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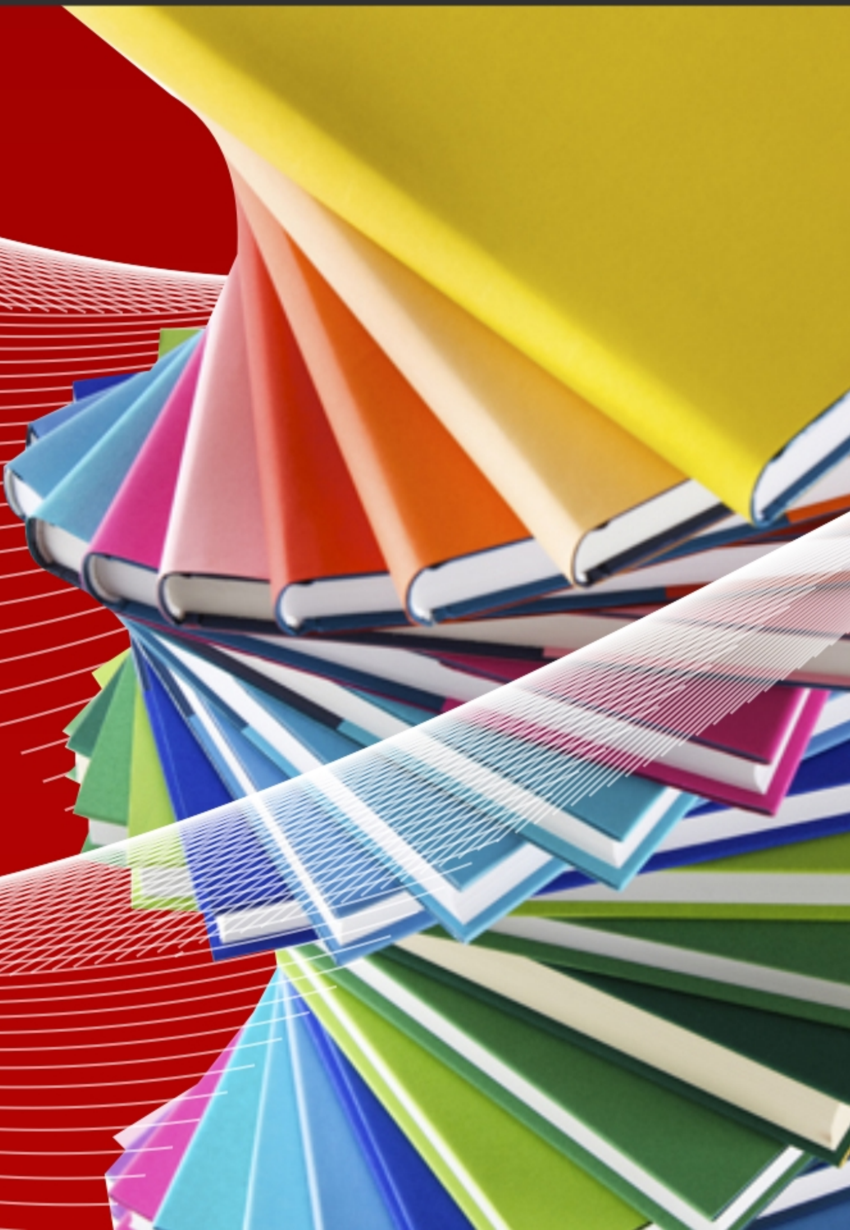

Analysis of Shear Wall Transfer Beam Structure

by

LEI KA HOU

Final Year Project report submitted in partial fulfillment

of the requirement of the Degree of

Bachelor of Science in Civil Engineering

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Faculty of Science and Technology

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DECLARATION

I declare that the project report here submitted is original except for the source materials explicitly acknowledged and that this report as a whole or any part of this report has not been previously and concurrently submitted for any other degree or award at the University of Macau or other institutions.

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APPROVAL FOR SUBMISSION

The project report entitled "**Analysis of shear wall-transfer beam structure**" was prepared by Lei Ka Hou in partial fulfillment of the requirements for the Degree of Bachelor of Science in Civil and Engineering at the University of Macau.

Endorsed by,

Signature : ______________________________

Supervisor : Prof. Iu Vai Pan

ABSTRACT

The aim of this paper is to investigate the structural behavior and both the stresses in the shear wall and in the transfer beam, which is usually placed at the first floor to support the shear wall to make a large opening at ground level. This paper presents an analysis and investigation of the structural behavior of transfer beam-shear wall systems in tall buildings with different amount of span of shear wall and geometry such as, span length, size of wall, beam and column. The different between normal deep beam and the transfer beam which supporting shear wall is that for normal deep beams, the estimation for structural behavior and failure mechanism can be done by span/depth ratio table but not for that kind of transfer beam.

This paper mainly investigates the effects of stress in lower part of shear wall and transfer beam due to different geometry and relevant parameters of the shear wall-transfer beam system such as span/depth ratio, stiffness of the supporting columns, and amount of span of the shear wall. All of models in this paper were analyzed by computer software ABAQUS which is a structure analysis program based on finite element method. The result has shown the significant effects of stress due to the interaction of the different amount of span and geometry of shear wall, transfer beam and column. Conclusions of the investigation show the structural behavior, analysis and parametric studies.

ACKNOWLEDEMENT

The author would like to express his gratitude sincerely to the supervisor Professor Iu Vai Pan for his valuable suggestions and kind supervisions. Besides, the author would also like to thank family and friends for spiritual supporting.

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CHAPTER 1 INTRODUCTION

1.1 General

Tall buildings emerged in the late nineteenth century in the United States of America. Therefore, structural systems for tall building were rapidly developed from that time. With different efficient height limit, the interior structures can be classified as rigid frames, braced hinged frames, shear wall frames and outrigger structures. Shear wall is a one type of lateral load resisting system usually used in tall buildings. The effective height limit for using shear wall combined with rigid frame as lateral load resisting system is around 70 meters.

The advantage of using shear wall is that it can resist lateral shear by concrete shear wall effectively. The representative tall buildings that using shear wall as lateral resisting system are 77 West Wacker Drive (Chicago, USA, 50stories, 203.6m) and Casselden Place (Melbourne, Australia, 43 stories, 160m) which show at Fig. 1.1 and Fig. 1.2 respectively. The disadvantage of using shear wall as a lateral system is that it would limit the design of floor plan of ground floor if the shear wall is directly supported by foundation. Therefore, shear wall are sometimes sitting on a deep transfer beam, which takes all vertical load and lateral load from shear wall, then spread to widely spaced big columns to vacate a large open space at ground floor. However, the loading supported by transfer beam is very large and complicated because much more parameters can affect the structural behavior due to the interaction between shear wall and transfer beam.

Figure 1.1 77 West Wacker Drive

Figure 1.2 Casselden Place

1.2 Objective of study

The study concentrates on the behavior of shear wall-transfer beam structure for tall building. This paper mainly investigates the behavior of interaction with various independent parameters. The scopes of investigation are listed below:

1. The structural behavior of shear wall in shear wall-transfer beam system while considering the interaction between shear wall, transfer beam and columns and the geometry of these elements.
2. The structural behavior of transfer beam in shear wall-transfer beam system with different geometry of the system.
3. The effects of stress distribution due to the different geometries of beam and columns.

1.3 Review of previous research

Shear wall is a very effective lateral resisting system. However, the existence of shear wall usually affects the design of floor plan. Therefore, the shear wall-transfer beam system has been investigated by numerous researches so that the larger openings at ground floor can be achieved to give more space for architect to design the floor plan. However, most researchers concentrated on the behavior of transfer beams and shear wall in simple system. The geometry or relevant parameter of shear wall-transfer beam system seems less important before. From resent year, the structural development in tall building has been rapidly evolved. Therefore, the effect of structural behavior due to geometry or relevant parameter of shear wall-transfer beam system has been given more importance.

Jawaharlal, P. (1996) has investigated the behavior of shear wall-transfer beam system. The results of paper have been cataloged in following:

1. In shear wall-transfer beam system, the region in the shear wall above the height equal to L, the span length of transfer beam, from the wall-beam interface can be considered as interactive zone. When shear wall subjects a distributed in-plane load toward to the transfer beam, the vertical stress distribution at the interactive zone present as an "arch" shape along horizontal direction. There are two kinds of arches which are primary arch and secondary arch which are responsible to transfer the major part of load to exterior support regions and transfer the remaining part of load to exterior and interior support regions respectively. Fig. 1.3 shows the primary arch and secondary arch graphically. For a single span shear wall-transfer beam system, only the primary arch effect occurs and for the two span case of shear wall-transfer beam system in paper, both primary and secondary arch effect occurs and the vertical stress at support can be increase to two times of original applied load.

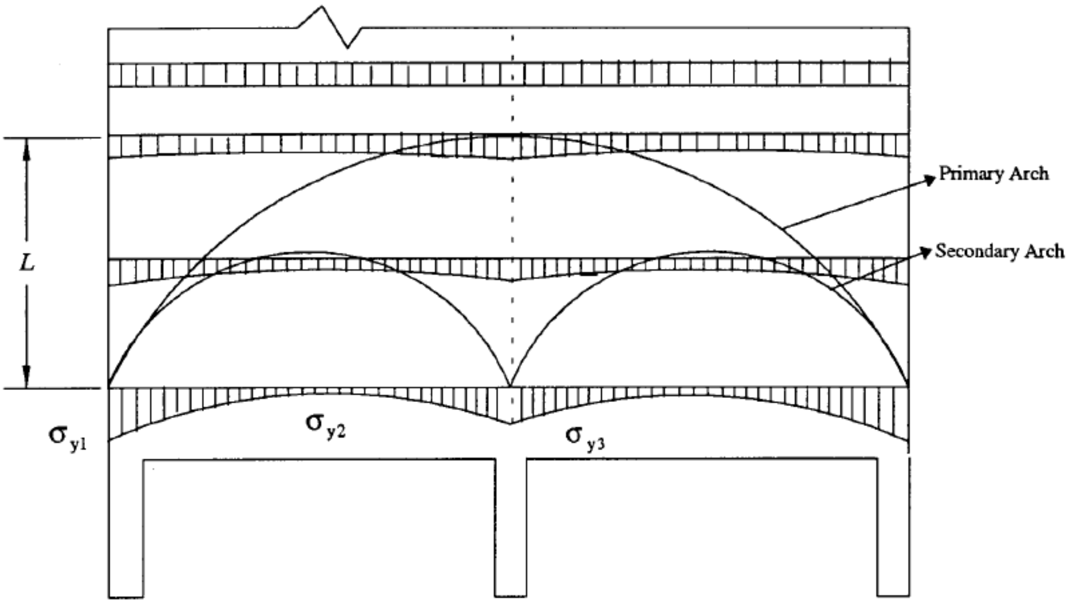


Figure 1.3 Distribution of vertical stress

2. Within the interactive zone which is just mentioned above, there is special effect for horizontal stress, vertical stress and also shear stress. However, areas in shear wall which above the interactive zone, the effects of these stresses disappear rapidly. For elements which are not in the interactive zone, the vertical stress distribution is the same as the load added on the top of shear wall. Moreover, The horizontal stress and shear stress are approximately equal to zero, which means there is no horizontal and shear interaction for those elements which out of the interactive zone. Fig. 1.4 and Fig. 1.5 show the distribution of horizontal stress and shear stress distribution in shear wall respectively.

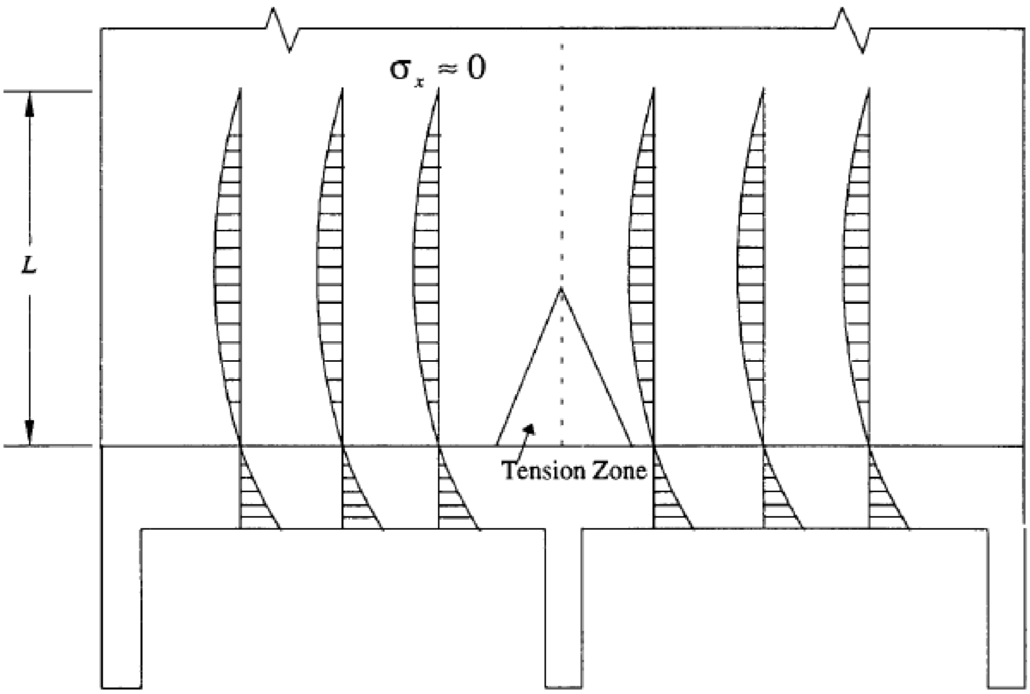


Figure 1.4 Distribution of horizontal stress

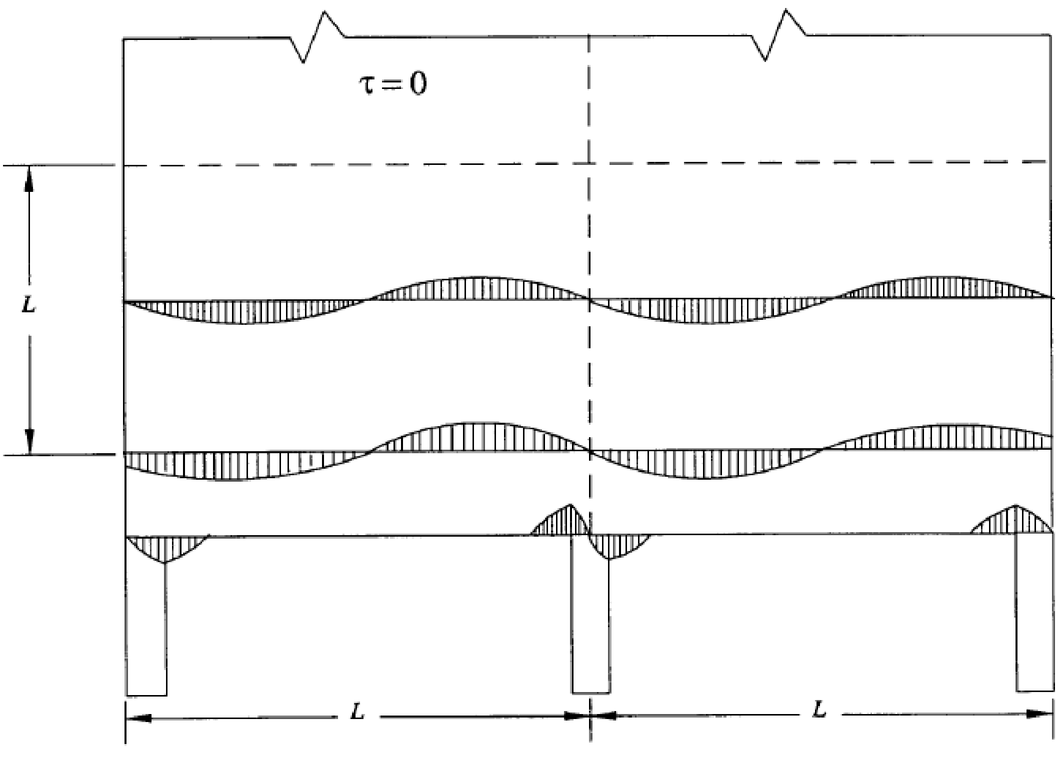


Figure 1.5 Distribution of shear stress

3. Shear wall is always in compression in both vertical direction and horizontal direction when it subjects an in-plane load toward to transfer beam. However, for example in two span case of shear wall-transfer beam system, there is a tension zone in the shear wall above the interior column which is approximately triangular in area. The base and height of the triangular tension zone are approximately 1.8-2.4 h_c. Within this zone, the horizontal stress is positive and the lower element in position, the larger tensile stress occurs. The tensile zone can be recognized in Fig. 1.6 graphically.

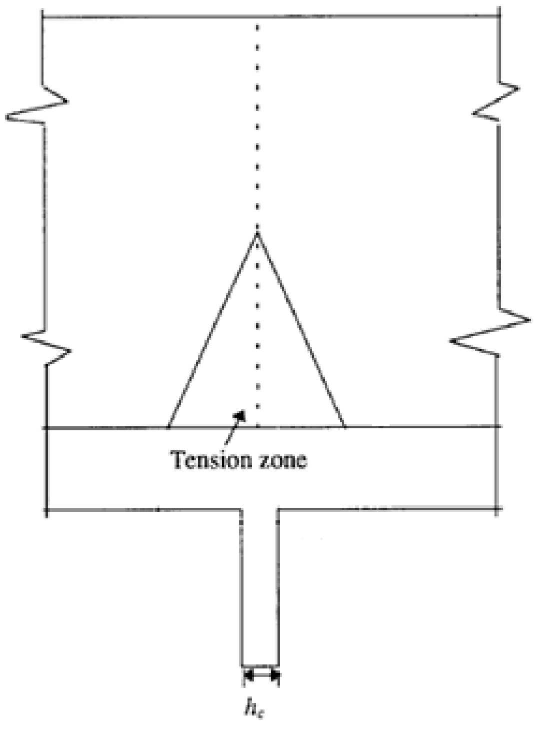


Figure 1.6 Triangular tension zone

1.4 Scope of work

After the literature review, some of basic behaviors in shear wall have been shown like the arch shape effect on the vertical stress of the lower part of shear wall and the triangular tensile zone at shear wall above the interior support. Therefore, there are many interesting studies that can be investigated. The mainly scope of work in this paper is to present the structural behavior and analysis of different geometry of shear wall-transfer beam system so that some kind of table like span/depth ratio can be built up which can be used to estimate the geometry parameters of shear wall-transfer beam system in different situation. Analysis of different considerations is separated in several chapters. The following is the brief introduction about each chapter.

In Chapter 2, the modeling concept is discussed. For this paper, the method for investigation is based on finite element method. Therefore, the concept of finite element would be discussed. Besides, in order to obtain results in using ABAQUS, there are series of steps and some of assumption which is needed to construct a model. Therefore, the steps to construct a shear wall-transfer beam system in ABAQUS are also discussed. Moreover, to obtain results using finite element program, there is one step called "meshing" which is one of step in ABABUS, is to divide each partition to be numerous elements to perform the finite element equations to each element. The accuracy of results depends on the size of element. However, the size of elements should not be too small because it is not efficiency. Therefore, the size of elements is investigated which can obtain an accurate results in effective manner.

In Chapter 3, there are divided in to two parts. The first part is that the total length of in-plane loaded shear wall and transfer beam is fixed. The arching action over the supports can be highlighted with different span and span length. The vertical stress and shear stress distributions at certain depths are plotted to clear the parameters which affect interaction of shear wall-transfer beam system. The second part is that the total length of span is fixed to see the stresses distribution when there is different amount of span. Therefore, the behavior of stresses obtained from these two parts can be compared to get more detail about the stresses effect due to parameters of span.

For normal beam, the estimation of size of beam can be checked by span depth ratio table. However, these tables are not available for the transfer beam in shear wall-transfer beam system because for the transfer beam supporting in-plane loaded shear-wall, the interaction of shear wall and transfer beam would affect the result. In chapter 4, the effect of stresses due to different depth of beam is investigated while the span length is fixed.

The overall conclusion of this paper is discussed in Chapter 5.

1.5 Coordinate system and unit

In this paper, the coordinate system of all models is set. As all models are 2-D problem, therefore the coordinate for models can just define in two directions. To match the global axis used as usual, the horizontal axis set as x-axis and the vertical axis set as y-axis.

The unit for this paper is in International system (SI unit). The unit for length is meter and the unit for force is kN. Therefore, for the distributed in-plane load adding on the top of shear wall in shear wall-transfer beam system, the unit is kN per meter. Besides, the finite element program ABAQUS which is a dimensionless program. Therefore, it should be cautioned that the unit of all data must be the same when modeling. For all of stresses obtained from ABAQUS, the unit is kN per meter square.

1.6 Notation

In this paper, there are some of parameters will be used to obtain a better and reasonable comparison on different stresses. These parameters are introduced in this section.

1.6.1 Geometric and load parameters

There are some geometric and load parameters that would used in this paper. Below shows the definition of those parameters:

L: Length of span

d: Depth of transfer beam

t: Thickness of shear wall

w: Distributed in-plane load per unit length

P: Pressure

1.6.2 Vertical stress σ_y

The vertical stress is the stress that is induced by external force in the vertical direction. In finite element modeling, there is a vertical stress at each node which can show the variation of vertical stress at any point. Besides, it can also show the behavior of the model at a certain point. If the vertical stress is shows in positive value, which means the element at that location is subjected to a compression force.

1.6.3 Horizontal stress σ_x

The horizontal stress is the stress that is induced by external force in the horizontal direction. In finite element modeling, there is a horizontal stress at each node which can show the variation of horizontal stress at any point. Besides, it can also show the behavior of the model at a certain point. If the horizontal stress is shows in positive value, which means the element at that location is subjected to a compression force.

1.6.4 Shear stress τ

The shear stress is the stress that is induced by external force between two elements. In finite element modeling, there is a shear stress at each interface of two elements which can show the variation of shear stress at any interface.

1.6.5 Vertical stress parameter

In order to obtain the reasonable results and ratio to present the vertical stress distribution at a level, the dimensionless ratio, α which is the vertical stress parameter developed to show the vertical stress variation. Below shows the equation of the vertical stress parameter:

$$\alpha = \frac{\sigma_y t}{w} \quad (2.1)$$

where

α: The vertical stress parameter

σ_y: The vertical stress

t: The thickness of shear wall

w: The distributed in-plane load per unit length

1.6.6 Horizontal stress parameter

In order to obtain the reasonable results and ratio to present the horizontal stress distribution at a level, the dimensionless ratio, β which is the horizontal stress parameter developed to show the horizontal stress variation. Below shows the equation of the horizontal stress parameter:

$$\beta = \frac{\sigma_x t}{w} \tag{2.1}$$

where

β: The horizontal stress parameter

σ_x: The horizontal stress

t: The thickness of shear wall

w: The distributed in-plane load per unit length

1.6.7 Shear stress parameter

In order to obtain the reasonable results and ratio to present the shear stress distribution at a level, the dimensionless ratio, γ which is the shear stress parameter developed to show the shear stress variation. Below shows the equation of the shear stress parameter:

$$\gamma = \frac{\tau t}{w} \quad (2.1)$$

where

γ: The horizontal stress parameter

τ: The horizontal stress

t: The thickness of shear wall

w: The distributed in-plane load per unit length

CHAPTER 2 MODELING

2.1 Introduction

Shear wall-transfer beam system is not like normal beam that can estimate the size and behavior by span/depth ratio. The structural behavior of shear wall-transfer beam system is sometimes hard to predict because the interaction between shear wall, transfer beam and column is very complex. Therefore, the powerful structural analysis method is used in this paper to perform the structural analysis which is finite element method. ABAQUS is one of structural analysis software which based on finite element method. The computation is performed with the finite element code ABAQUS in this paper to generate the interactive forces and stresses at different locations for all models. The axis used in this paper is global axis which presents horizontal direction as x-axis and vertical direction as y-axis.

2.2 Finite element method

Finite element method is a numerical method to solve engineering problems and mathematical physics. By this method, the approximate solution can be obtained but rather than analytical solutions. This method is useful for problems with complicated geometries, material properties and loadings where the solutions cannot be obtained analytically. The purpose of using finite element analysis rather than analytical solution is that finite element analysis can predict the performance and behavior of the design, and to identify the safety margin accurately. Moreover, the physical behaviors of a complex object can be understood. But for analytical solution the factor of safety is usually given by experience.

There are six steps involved in finite element method which are element discretization, primary variable approximation, element equations, Global equations, Boundary conditions and solving the global equations sequentially. The introduction about each step is presented following:

1. Element discretization

In this process, the geometry of investigating model is separated in many small regions, called finite elements. There are nodes defined on each element, or within the elements.

2. Primary variable approximation

In this step, a primary variable must be selected or assigned like a displacement or load adding on any point of the model. This variable is expressed in terms of nodal values.

3. Element equations

In this step, the element equation is generated as showing below:

$$[K_E]\{\Delta d_E\} = \{\Delta R_E\} \tag{2.1}$$

where $[K_E]$, is the element stiffness matrix which include those parameters about the material properties. $\{\Delta d_E\}$, is the vector of incremental element nodal displacements. $\{\Delta R_E\}$ is the vector of incremental element nodal forces. There is one element equation for each element.

4. Global equation

In this step, element equations are combined together to form global equations shown as below:

$$[K_G]\{\Delta d_G\} = \{\Delta R_G\} \tag{2.2}$$

where $[K_G]$, is the global stiffness matrix. $\{\Delta d_G\}$, is the vector of all incremental nodal displacements. $\{\Delta R_G\}$ is the vector of all incremental nodal forces.

5. Boundary condition

In this step, the boundary conditions are formulated and the global equations are modified. If there is loading applied on the model, the $\{\Delta R_G\}$ would be affected and if there is displacements on the model, the $\{\Delta d_G\}$ would be affected.

6. Solving the global equations

The global equations can be solved after step 5. Then $\{\Delta d_G\}$ can be obtained which is included the displacements at all the nodes. After $\{\Delta d_G\}$ is obtained, the secondary quantities such as stresses and strains can be calculated.

There are three main groups of finite elements which are 1-D element, 2-D element and 3-D element. In this project, 2-D element is used in analyzing models. Therefore, the following will be just focused on introducing 2-D element.

There are two branches in analyzing 2-D problem which are plane stress analysis and plane strain analysis. Plane stress analysis is used in problems such as a plate with some changes or with holes in geometry that are loaded in plane. Plane stress analysis is usually used in one of dimension of the model much smaller than the others while the load is applied on the in-plane direction. Therefore, the stress perpendicular to the x-y plane (the 2-D plane) is assumed to be zero. Plane strain analysis is used in problems such as the geometry of model in one direction is much larger than others. The load applied in x-y plane does not affect the z direction. Therefore, the strain normal to the x-y plane, and the shear strain in x-z plane and y-z plane are assumed to be zero. In this project, because the in-plane uniform distributed load is applied at the top of shear wall, the plane stress analysis is used to investigate the structural behaviors of the shear wall-transfer beam system.

2.3 Structural modeling

To simulate the shear wall-transfer beam system in ABAQUS, 2D planar modeling space is used because the size of thickness of those parts is relatively much smaller than the total length and the height of whole structure. The deformable type and shell base feature are chosen to simulate the planar shell parts which are used to model both of shear wall, transfer beam and columns. Moreover, the sections of all parts are used homogeneous solid section to simulate the behavior of in-plane loaded shear wall-transfer beam system, thus to ensure that there is no out of plane effect occurs. The tie constraints are used in the interfaces between shear wall and transfer beam, and also between transfer beam and columns to perform a perfect bonded in those interfaces so that there is no displacement occurs due to sliding between parts. The pin boundary condition is used in the bottom surfaces of columns. The mesh size depends on the size of model in different Chapters; the detail meshing size is discussed in Section 2.4. The plane stress element CPS4 is used in all parts. Fig. 2.1 shows the typical model which is investigated in this paper.

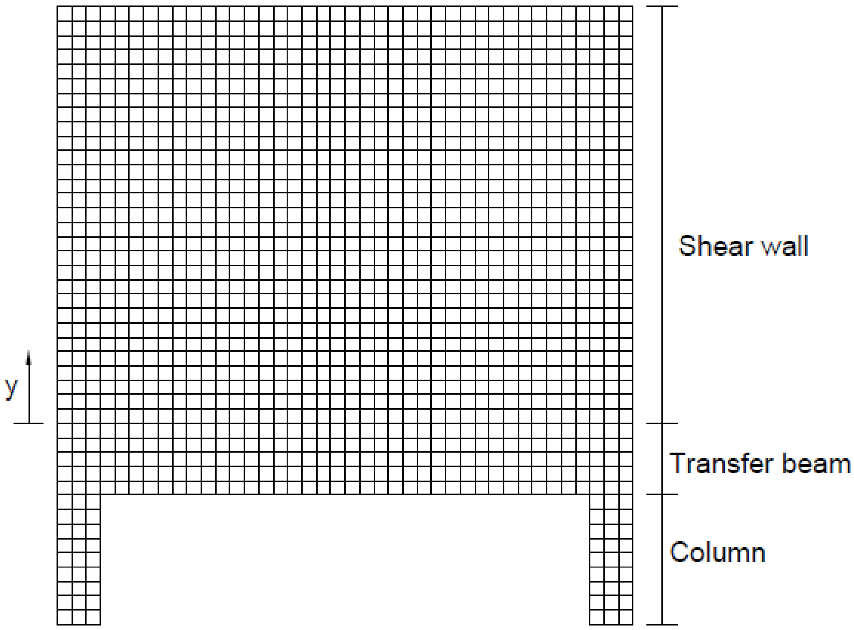


Figure 2.1 Typical meshed model

2.4 Meshing

2.4.1 Introduction

When the model is investigated by finite element method, meshing is necessary for a model to separate many small elements then a series of equations shown in Section 2.2 can be performed. The smaller elements in model meshed, the more accurate result can be obtained. However, the judgment of the number of each element should also be concerned because there is a certain number of each partition which can get an accurate result sufficiently and smaller element used in analysis request longer time and computing resources needed to obtain result. Therefore, a further smaller element is not necessary for the model to obtain results.

2.4.2 Meshing consideration

There are several considerations when deciding the number of element. Below shows some considerations in this project:

- The size of model
- The stress variation
- The size of adjacent partition

1. The size of model

   This is one of consideration when meshing a model. For 2-D problem, there are two dimensions of length which should be meshed before performing analysis to obtain result for a model. Therefore, if the length is larger, there should be more elements in that dimension. Moreover, the size of element should be smaller if the problem is just mainly on one of dimension in investigation.

2. The stress variation

   For most of problems, the stress may increase or decrease rapidly like near the point where adding a concentrated load or the regions near the column support.

Usually near those regions, the stress will increase rapidly because there are some boundary conditions or stiffer region. Therefore, the smaller element should be used in those regions to obtain an accurate result.

3. The size of adjacent partition

In order to get an accurate result through finite element method, the meshing of each adjacent partition should be consistent. That means both of two dimensions of the size of elements should be the same with the adjacent element. Therefore, the common node can be formed between elements and the result will be more accurate due to the deformation at common node is the same for those elements.

2.4.3 Modeling

In this section, the size of element request to obtain an accurate result is presented. Considering a simple example that is a one span shear wall transfer beam structure. The model is shown in Fig. 2.2 which shows three parts of partitions in forming a shear wall-transfer beam model.

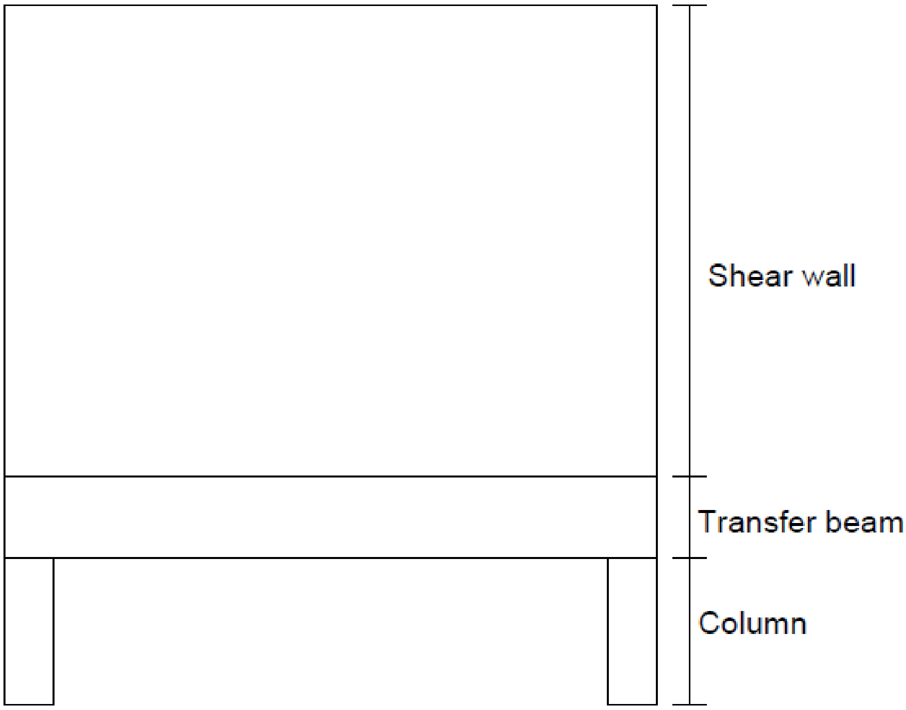


Figure 2.2 Simple model example

For the considerations listed above, the main investigating parts of a model are the lower part of shear wall and the transfer beam. Therefore, the shear wall and the transfer beam are chopped into several parts respectively. The separation of each partition is shown in Fig. 2.3.

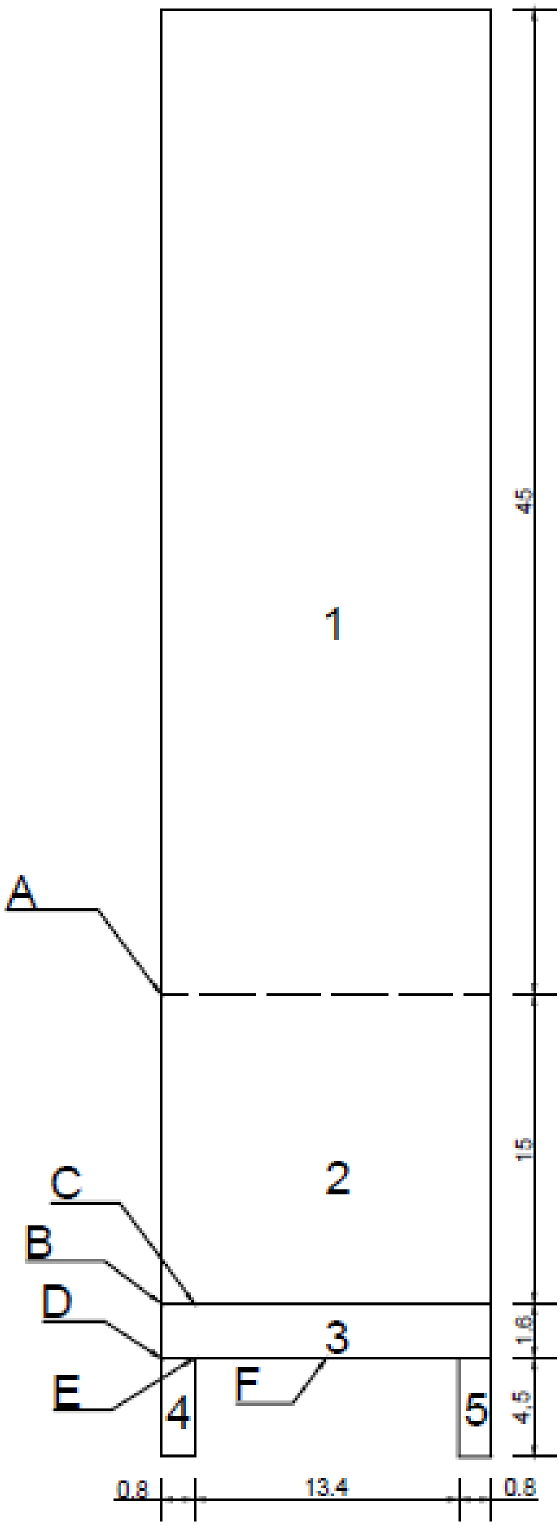


Figure 2.3 Typical sample partition

In Fig. 2.3, there are 1 to 5 parts. Part 1 and 2 are the upper part and the lower part of the shear wall respectively; part 3 is the transfer beam. Part 4 and 5 are two columns. In this paper, the main investigation partitions are the transfer beam and the lower part of shear wall. Therefore, at these two partitions the size of elements is defined as smaller than others to obtain an accurate result.

For the transfer beam, the horizontal stress distribution along the span will be investigated. Therefore, the elements in horizontal direction should be defined as smaller. Besides, the stress distribution along the transfer beam at mid span will also be investigated. Therefore, the elements in vertical direction should also be defined as smaller. Moreover, the stress variation can be changed rapidly near the supporting columns. Therefore, the size of element in transfer beam should be smaller at those regions.

For the shear wall, the elements in the upper part of shear wall can be reduced because this is not the investigation part. However, for the lower part of shear wall, the vertical stress and shear stress along the span will be investigated. Therefore, the elements in horizontal direction should be defined as smaller.

There is a set of model which containing five different meshed models in this section to investigate the convergence of the result due to meshing, named model set A. For each model, six points are taken out as reference point to compare the difference between each model named as point A, B, C, D, E and F which are shown in Fig. 2.3. The meshing of models is shown in Fig. 2.4, Fig. 2.5, Fig. 2.6, Fig. 2.7 and Fig. 2.8. In these figures, the number shown is the number of element.

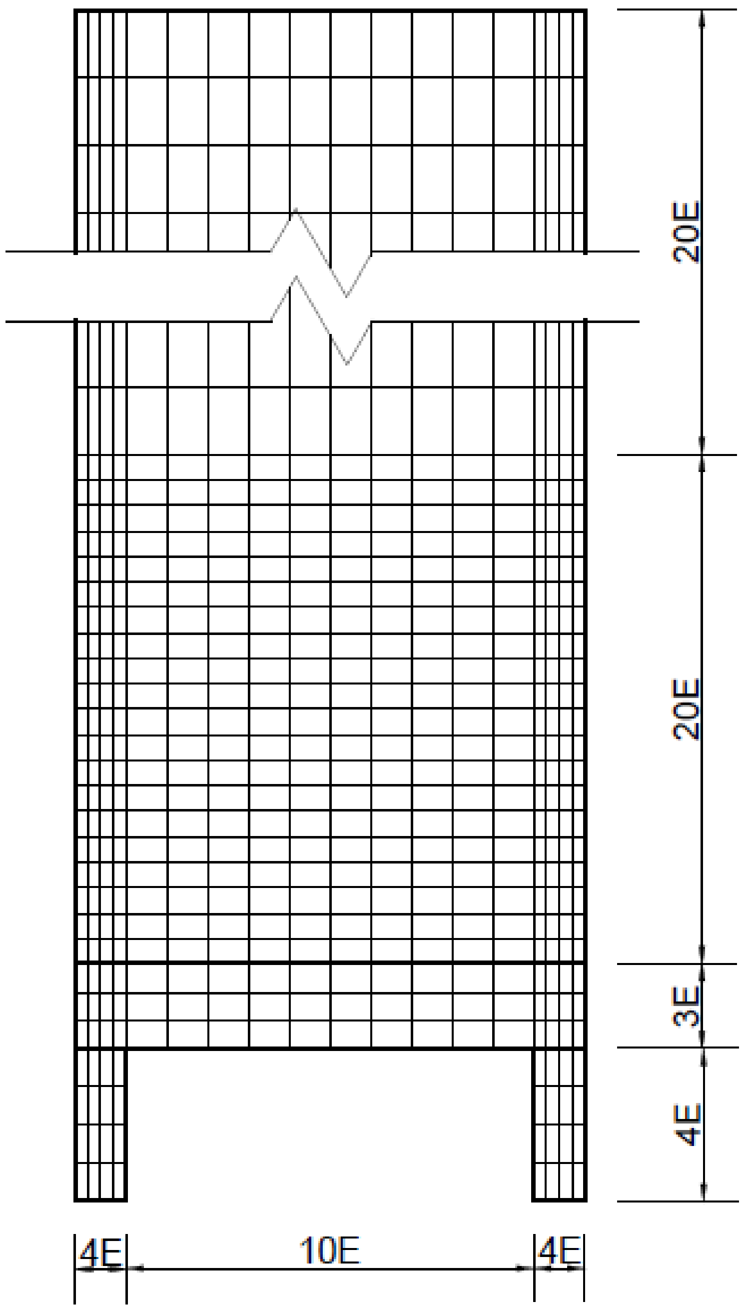


Figure 2.4 meshed model (model A-1)

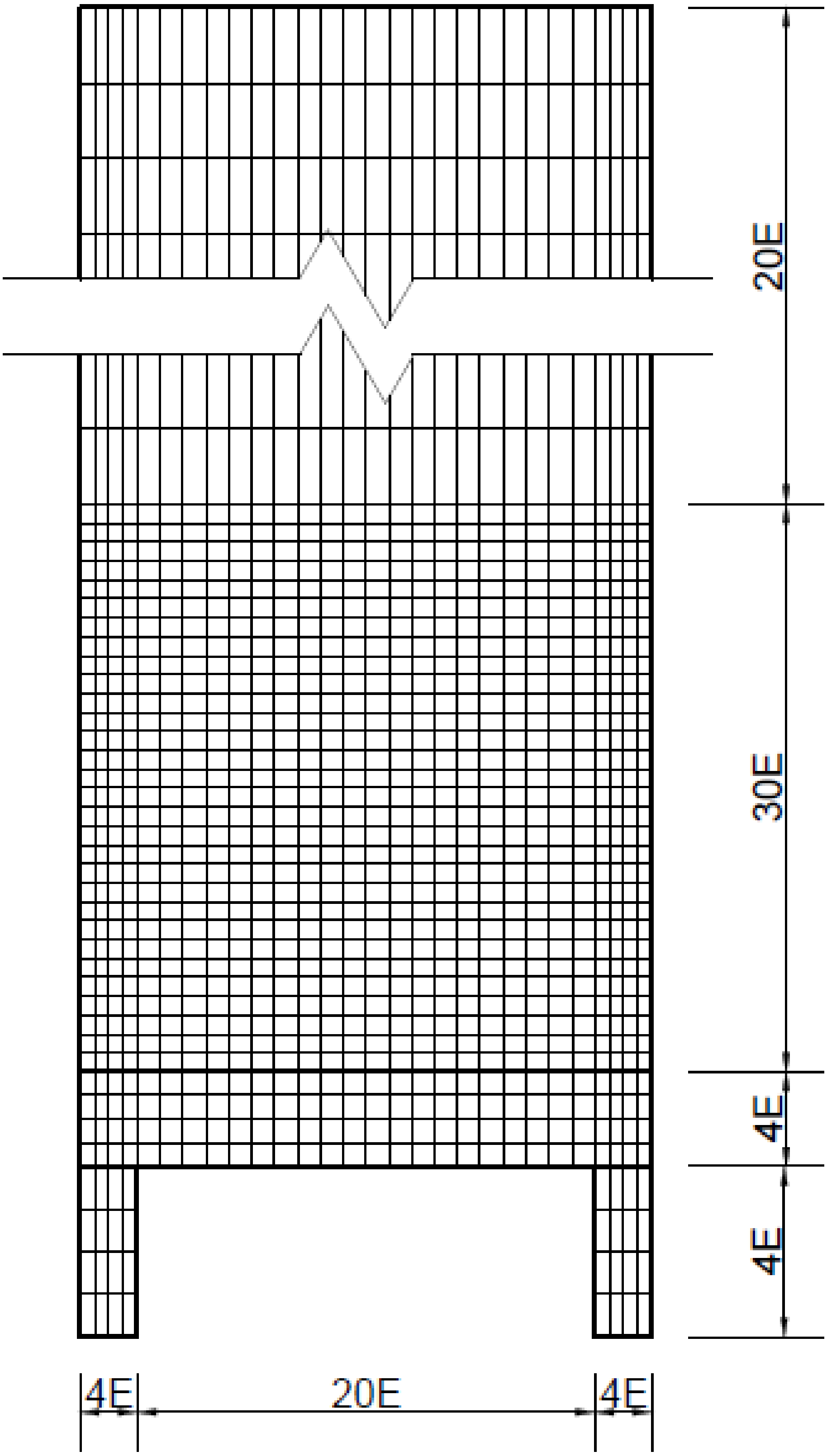


Figure 2.5 meshed model (model A-2)

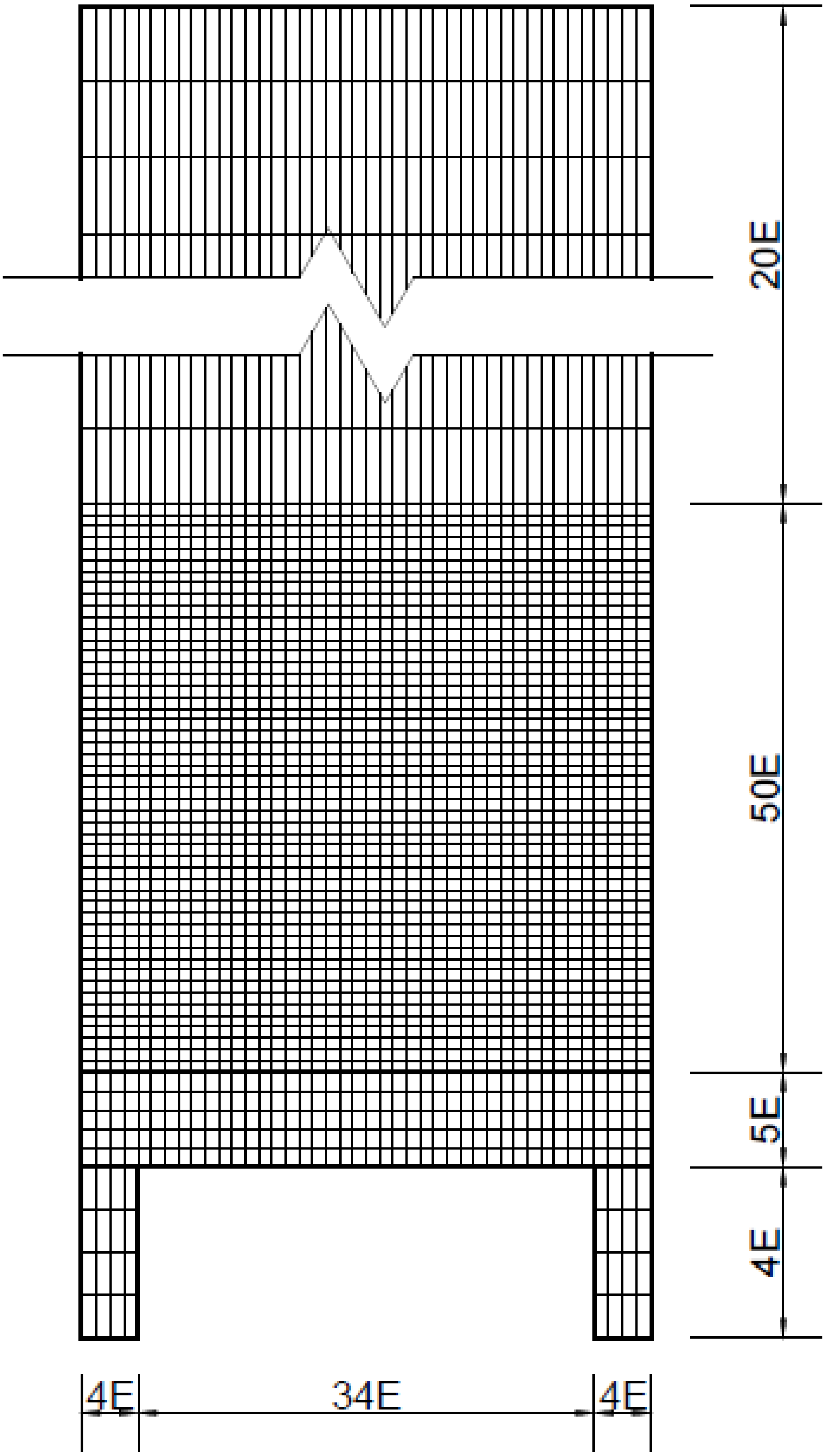


Figure 2.6 meshed model (model A-3)

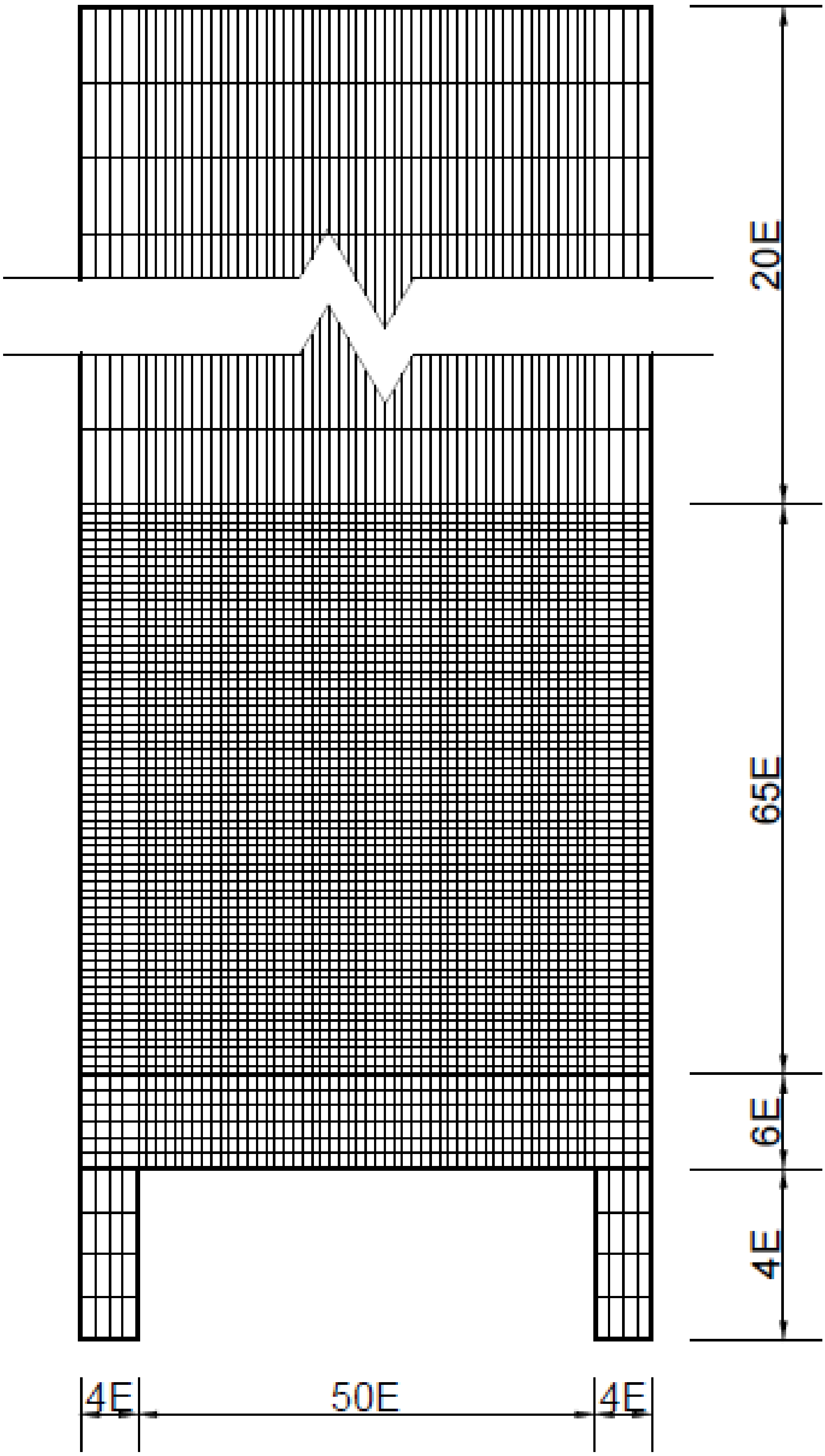


Figure 2.7 meshed model (model A-4)

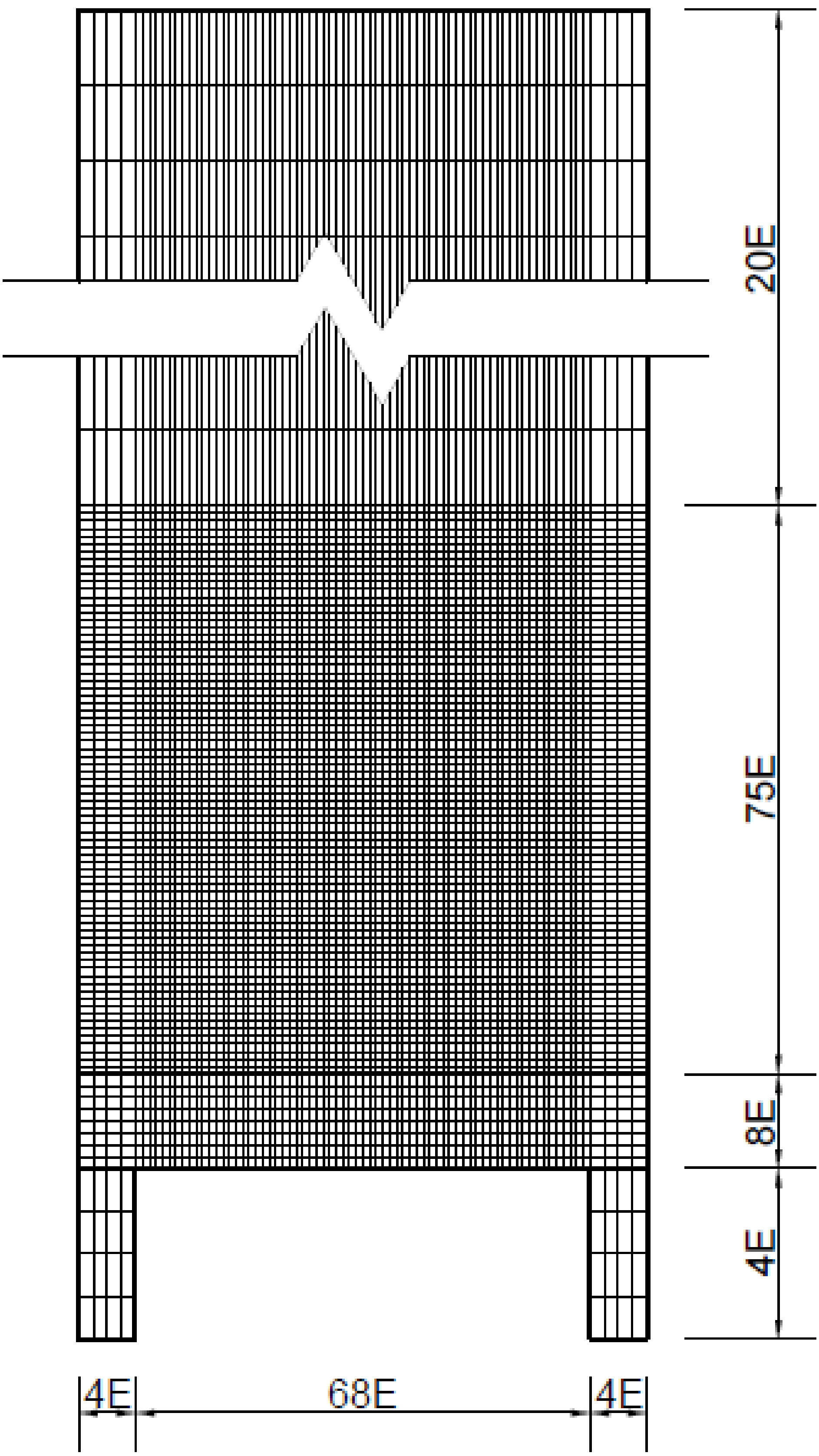


Figure 2.8 meshed model (model A-5)

2.4.4 Method of comparison

After those models are analyzed by ABAQUS, the magnitude of stress at any point of the model can be known. To investigate the convergence of the stress due to the size of meshing, the comparison of the stress of each model at the six points mentioned above should be performed.

2.4.5 Stress at reference point

There are six reference points for each model to compare the stress variation due to the size of element. However, the vertical stress is the main concern in the lower part of shear wall because it can show the arch effect due to the interaction between shear wall and transfer beam. Therefore, the comparison of stress at point A, B and C for each model is based on the vertical stress comparison. On the other hand, the main concern in the transfer beam is the horizontal stress. Therefore, the comparison of stress at point D, E and F for each model is based on the horizontal stress comparison.

2.4.6 Result

In this section, a series of figures are plotted to show the difference of stress between models at each point. For each figure, the x-axis presents the number of element used in the partition at that direction of investigating stress. The y-axis presents the ratio of stress, α to show the variation of stress. Fig. 2.9 to Fig. 2.14 shows the stress ratio results.

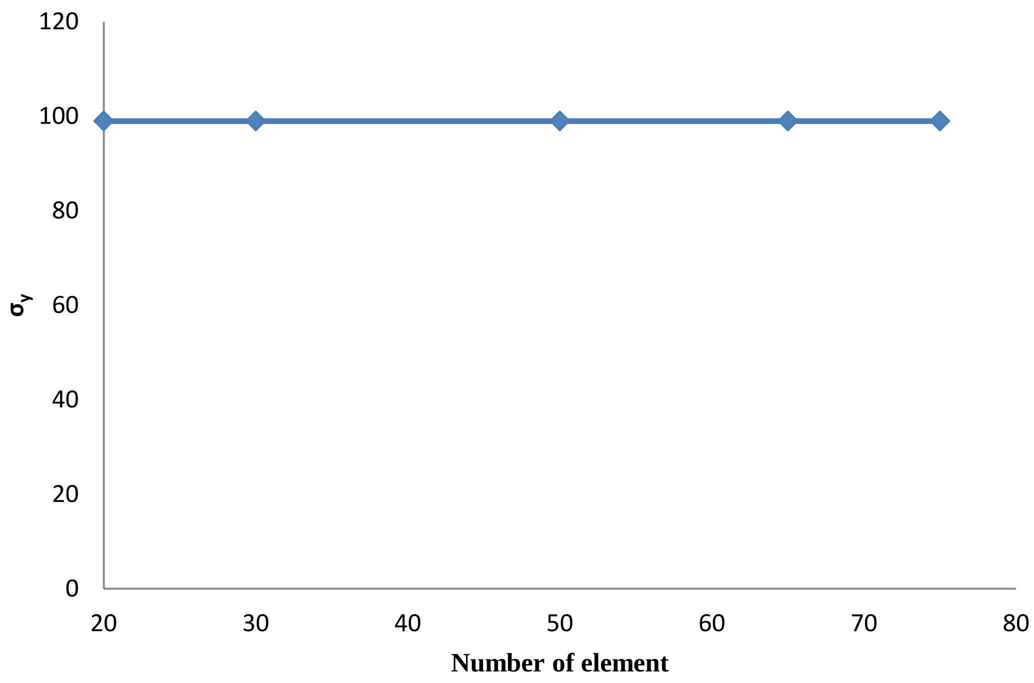


Figure 2.9 Convergence of vertical stress at point A

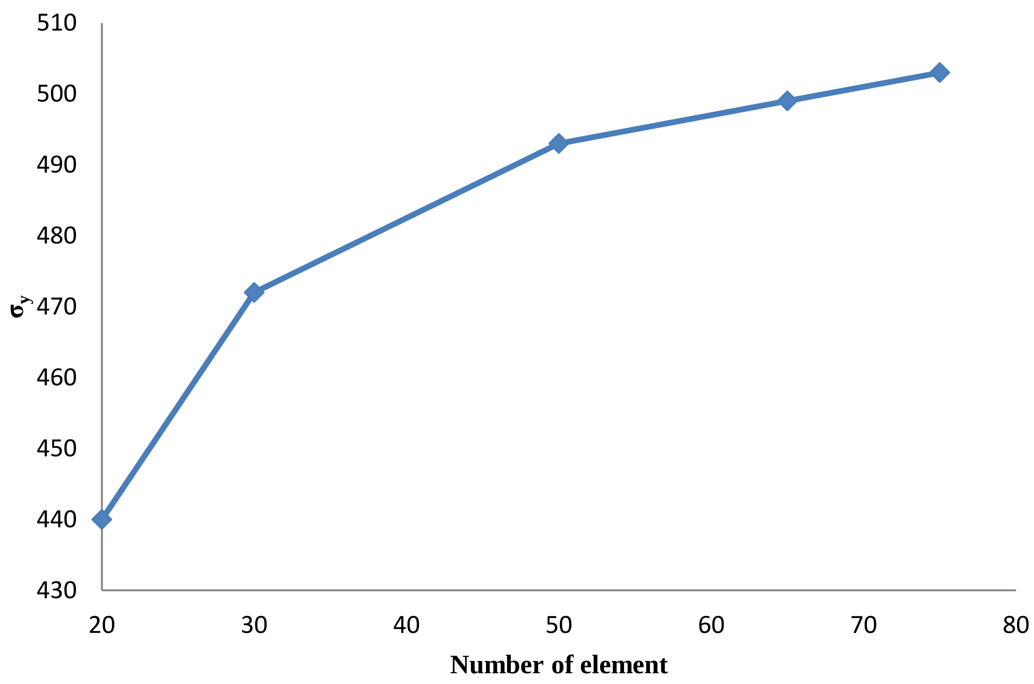


Figure 2.10 Convergence of vertical stress at point B

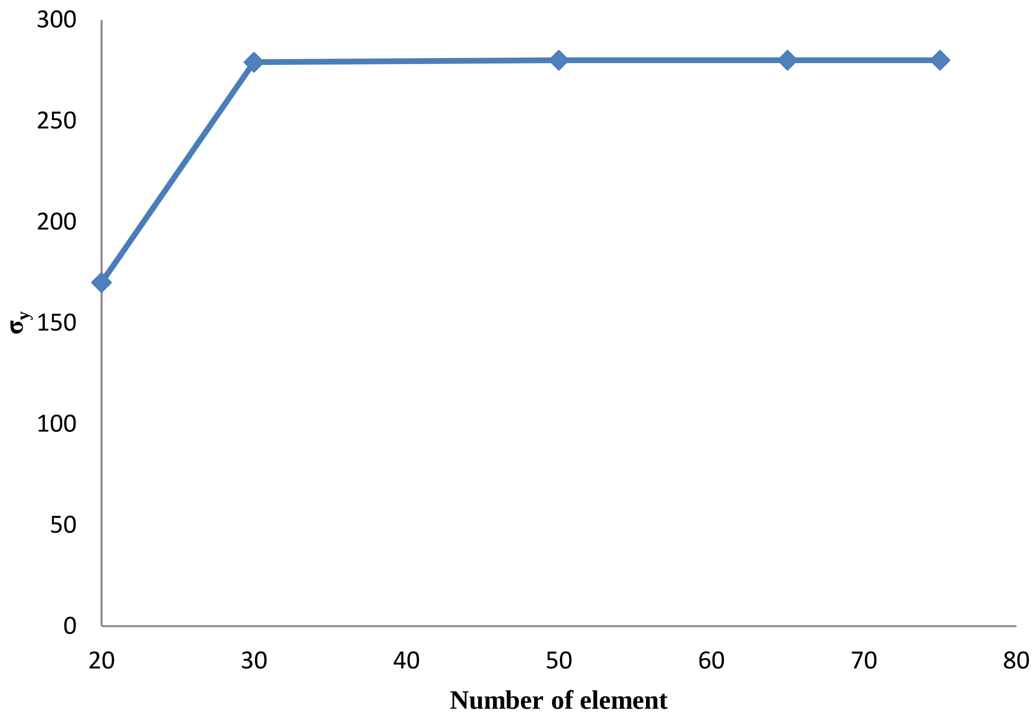


Figure 2.11 Convergence of vertical stress at point C

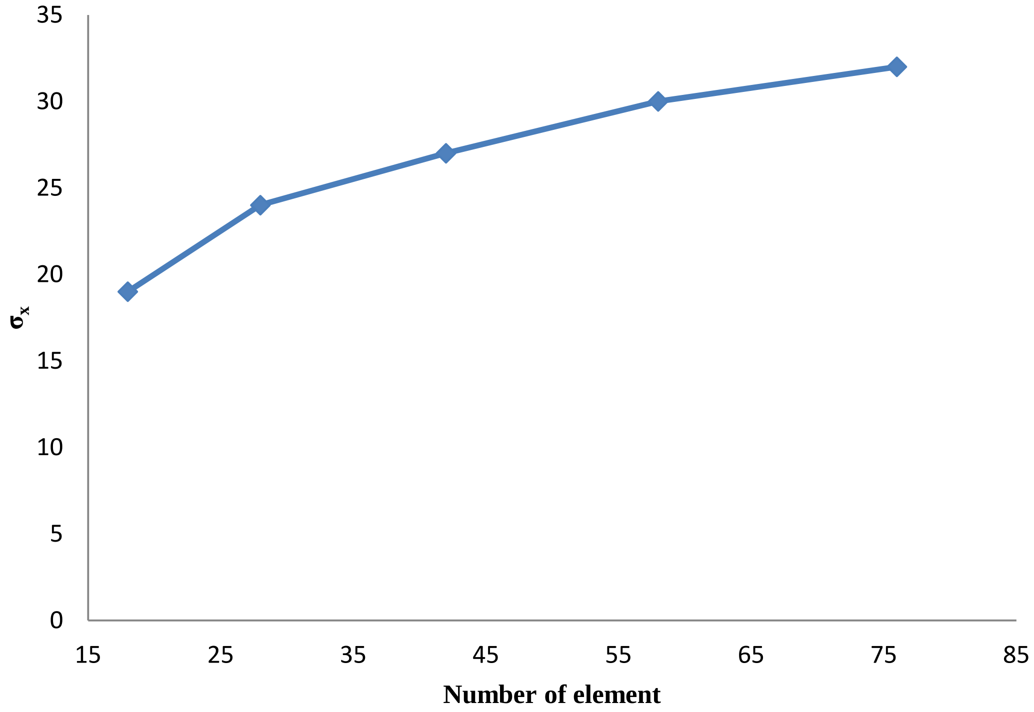


Figure 2.12 Convergence of horizontal stress at point D

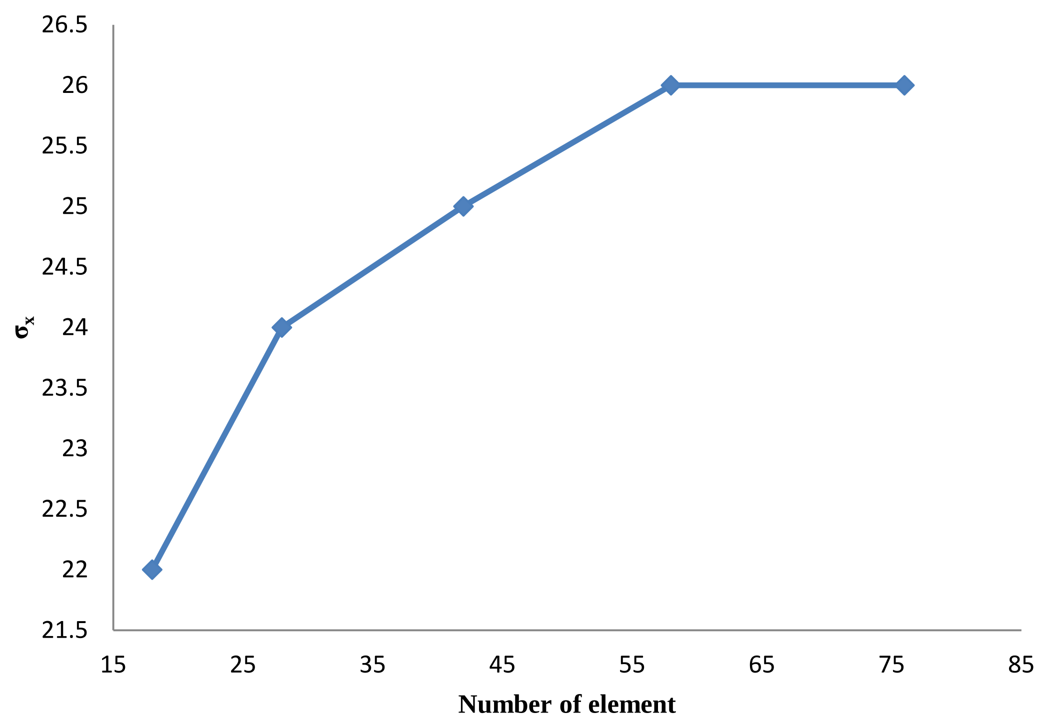


Figure 2.13 Convergence of horizontal stress at point E

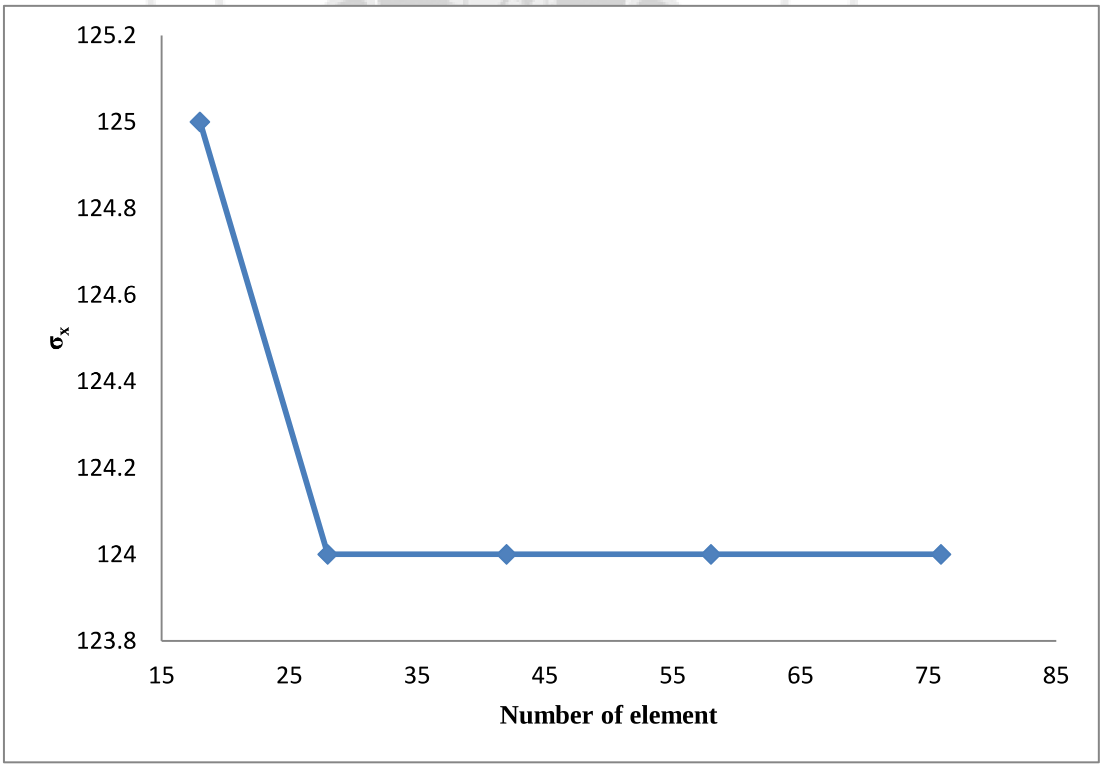


Figure 2.14 Convergence of horizontal stress at point F

From Fig. 2.9, it shows the vertical stress difference between different models at point A. The result shows there is no different of the vertical stress when the size of element becomes smaller and the vertical stress is remain the same as applied in-plane load on the top of the shear wall. Therefore, the size of element at the upper part of shear wall can be remained the same as those model.

From Fig. 2.10, it shows the vertical stress difference between different models at point B. The figure shows the vertical stress variation is a little bit large compare with model 1 and model 5 because the vertical stresses at point B are 440 and 503 for model 1 and model 5 respectively. However, the figure shows that the vertical stress obtained from model 3 and model 4 are also tended to constant. Therefore, the size of element for the lower part of shear wall in vertical direction can use the same as model A-3 or model A-4.

From Fig. 2.11, it shows the vertical stress difference between different models at point C. The figure shows that the vertical stress tends to constant from the model A-2. Compare with the Fig. 2.10, which shows the size of the element at the lower part of shear wall should be the same as model A-3 or model A-4. Therefore, the size of element for the lower part of shear wall can be the same as model A-3.

From Fig. 2.12, it shows the horizontal stress difference between different models at point D. The figure shows that the horizontal stress tends to constant slowly. The horizontal stress obtained from model A-4 and model A-5 is 30 and 32 respectively where the different is acceptable. However, the horizontal stress is very small at this point compare to the stress obtained from the other points. Therefore, the size of element at this partition can be the same at model A-4.

From Fig. 2.13, it shows the horizontal stress difference between different models at point E. The figure shows that the horizontal stress tends to constant when the size of element becomes the same as model A-4. Compare with Fig. 2.12, which shows the size of element should also be the same as model A-4. Therefore, the size of element for the transfer beam in horizontal direction can be taken as the same as model A-4.

From Fig. 2.14, it shows the horizontal stress difference between different models at point F. The figure shows that from the stress obtained from model A-2, the stress keep consistent when the size of element becomes small. Therefore, the size of element can be remained the same as model A-2.

2.4.7 Conclusion

In this section, the effect of stresses due to the size of element is investigated for the sample model. For point A, the result shows that whatever the size of element is, the vertical stress at this point will not change simply because at that level, the vertical stress is still constant which means no arch effect on that level of shear wall. This is also evidenced by the previous paper. Therefore, the number of elements in the upper part of shear wall can be just the same as those models. For point B, D and E, the stress variation for models changed slowly because the stress variation is large at these points which are at the corner of the model. Especially for point E, that is the interior point at the corner of the column support and the transfer beam. For point C and F, the result shows the stress becomes constant quickly which is because at these points, the variation of stress is not that large compare to point B, D and E. Therefore, for the lower part of shear wall, the number of element should be used the same as model A-3. For the part of transfer beam which supporting by column, the size of element should be the same as model A-4 and for the interior part of transfer beam, the number of element should be the same as model A-3.

In order to obtain the accurate result of stress for models with any geometry for each partition from ABAQUS, the size of element for each partition should be calculated. With the geometry of model shown in Fig. 2.3 and the results discussed above, the size of element for each partition, which can obtain an accurate stress result, can be calculated. Table 2.1 shows the number of element which should be used to obtain an accurate result when model is be investigated.

Table 2.1 number of element for each partition

Partition	Number of element in x direction	Number of element in y direction
Upper part of shear wall	58	20
Lower part of shear wall	58	50
Transfer beam	58	6
Column	4	4

CHAPTER 3 EFFECT OF SPAN

3.1 Introduction

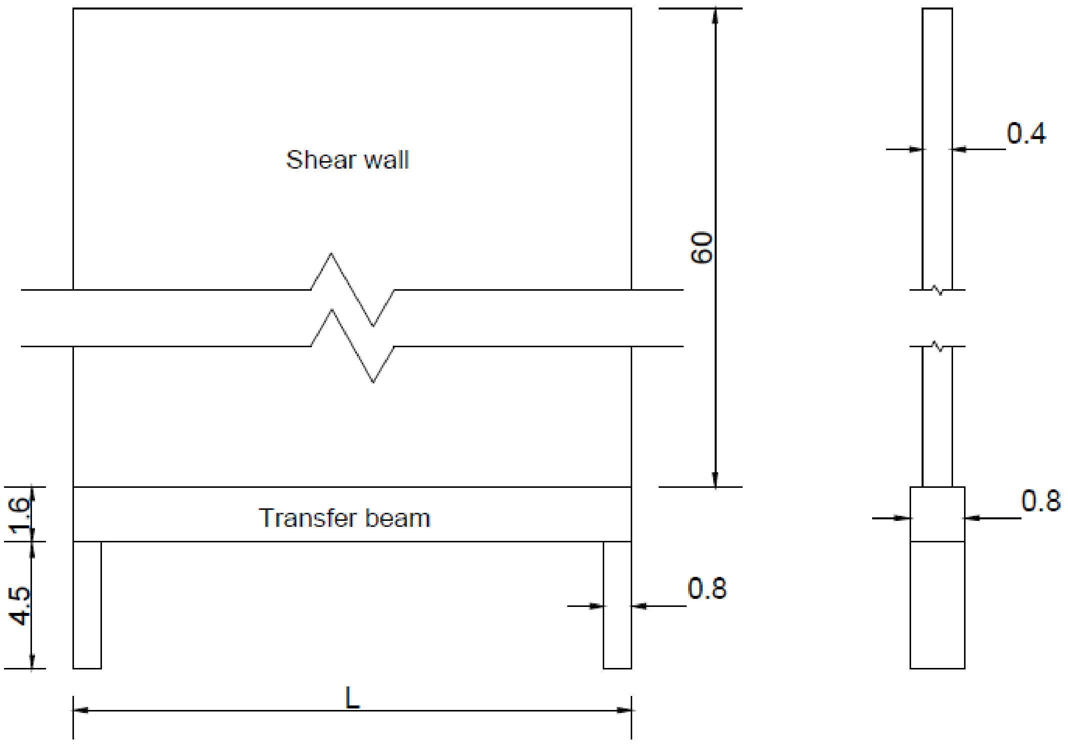
The main reason to use a transfer beam to support shear wall is that it can take all of vertical load and lateral load from shear wall and spread to columns. Therefore, the larger space opening can be obtained at ground floor. However, the space between columns is one of significant parameter that affects the structural behavior and stresses in lower part of structure. Besides, the interaction effects from the interior column or columns support have a significant effect on the structural behavior of shear wall like primary and secondary arch. With the different criteria or constraint of the length of shear wall, the length of each span is one of concern that affects the structural behavior of shear wall significantly. Moreover, the vertical stress can also increase significantly with different length of span.

In this Chapter, there are two different parts to investigate the effect of span for the shear wall-transfer beam system. The first part is that models investigated with a constant building width but different amount of span, the other part is that models investigated with a constant length of span and with different amount of span. There are two sets of models and for each set of model, there are three models which will be investigated in each part. Table 3.1 shows the length of span of each model for different parts.

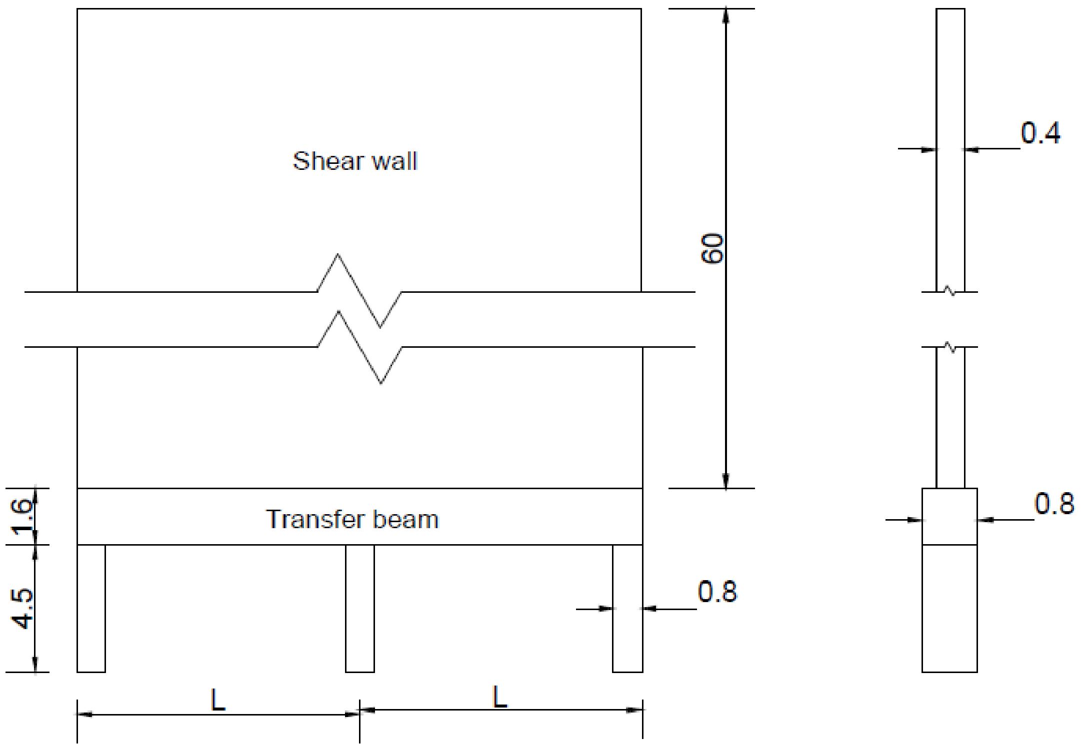
Table 3.1 Span length of models

	Span length (m)		
	Model 1	Model 2	Model 3
Total length fixed	15	7.5	5
Span length fixed	15	15	15

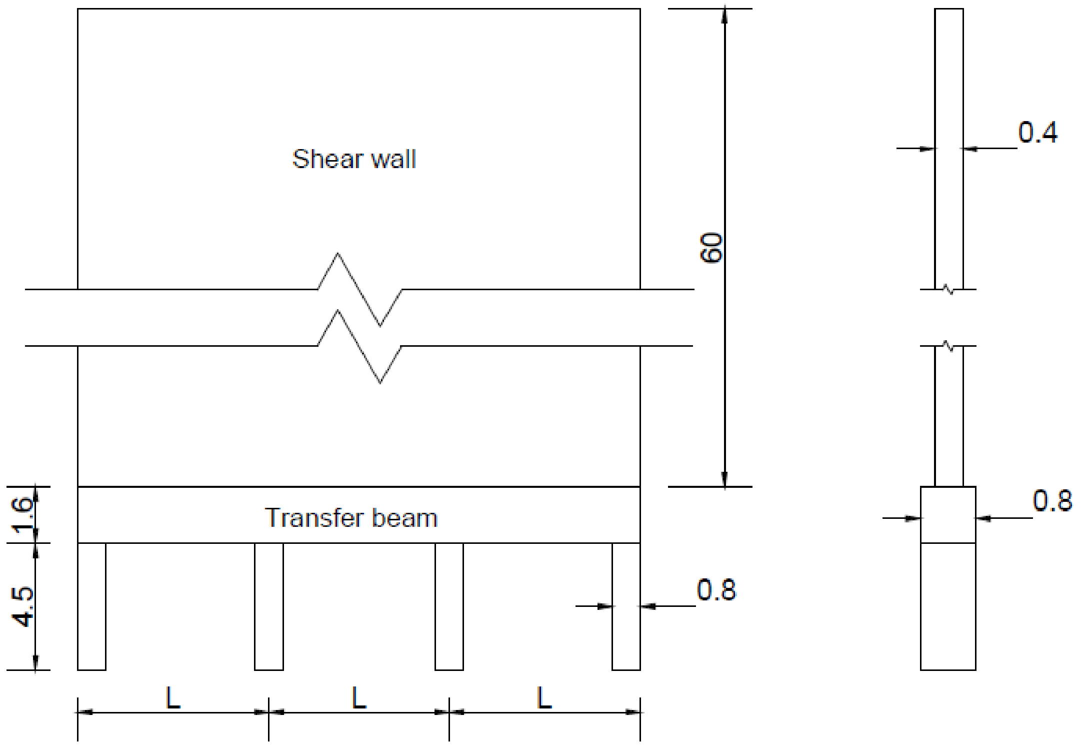
The geometry of models is shown in Fig. 3.1. These three models are simulated when the top of shear wall subject an in-plane pressure P toward to transfer beam where P equal to 100kN/m^2. Therefore, with the thickness of shear wall 0.4m, the distributed in-plane load w equal to 40kN/m.



(a) Model with one span (Model B-1)



(b) Model with two span (Model B-2)



(c) Model with three span (Model B-3)

Figure 3.1 Models with different span (Set B models)

3.2 Structural behavior

The structural behavior of a shear wall-transfer beam system subjected to vertical loading is very complex due to the interaction of shear wall and transfer beam. Besides, the interaction of exterior column and interior column is also a significant role in stress analysis. These three models can simulate the structural behavior in one span, two span and three span. Therefore, the shear wall-transfer beam system with more span can be also estimated based on these models. The details behavior of vertical stress in the lower part of shear wall can be investigated. Therefore, the primary arch effect and secondary arch effect can also be investigated. However, from previous research, the horizontal stress in shear wall is always in compression except the tensile zone which is above the interior support. Therefore, the location of detail investigation for horizontal stress is in the transfer beam because the horizontal stress in transfer beam is much larger than the horizontal stress in the tensile zone. The location of detail investigation for shear stress is in lower part of shear wall also because the shear stress in the lower part of shear wall is always larger than the shear stress which in the transfer beam. The positive value in stress means compression stress and negative value means tension.

3.3 Results and analysis

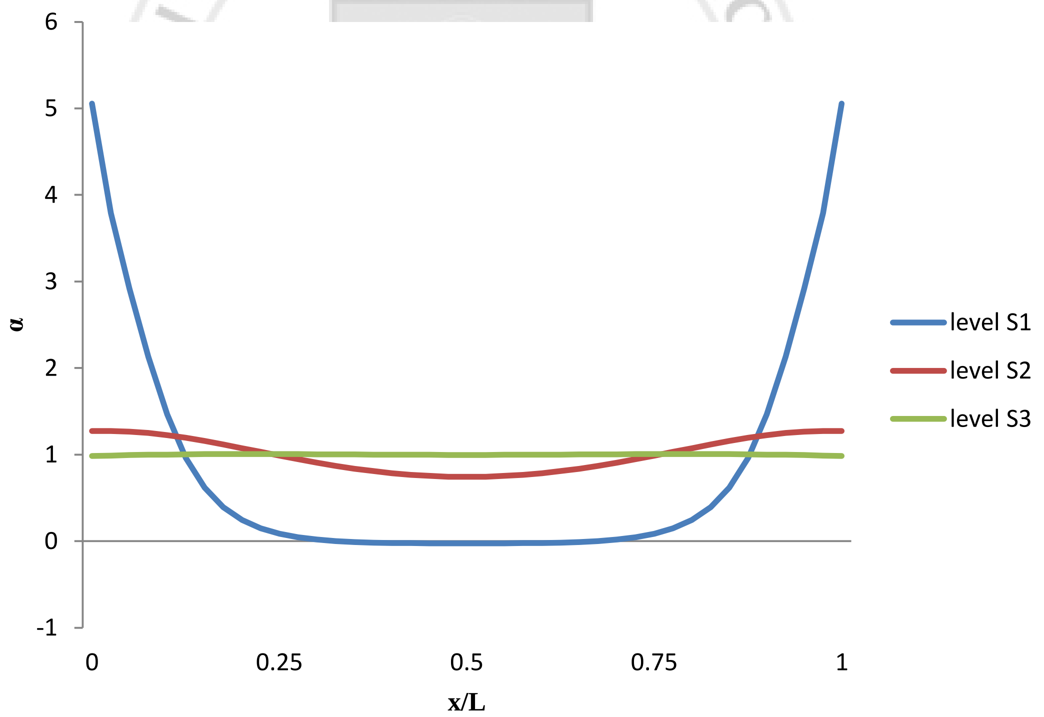
3.3.1 Constant building width

The lengths of span for each model have been presented previous. For this section, the total length of structure is fixed as 15 m. The length of span for two span and three span is divided equally which is 7.5m and 5m respectively.

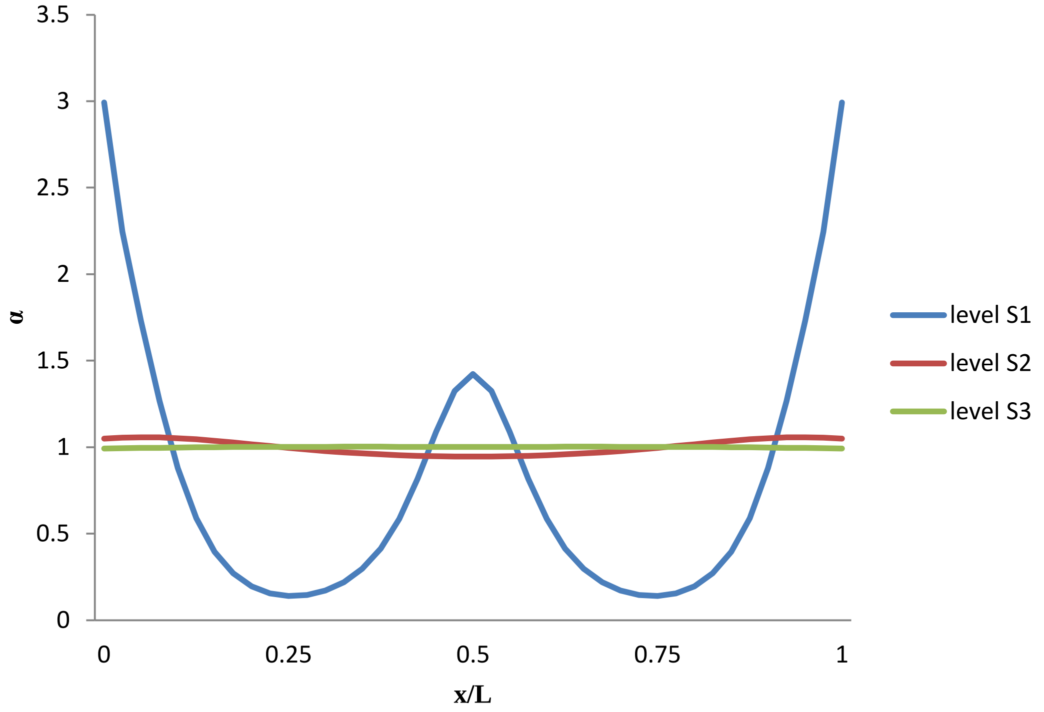
1. Vertical stress

In this section, the vertical stress distribution in the lower part of shear wall is investigated with different length of span but the fixed total length. The three models shown in Fig. 3.1 have been analyzed and for each model, the data of vertical stress have taken from three horizontal sections where are y/L=0, y/L=0.5 and y/L=1 (L is the span length of the model, in these three models, L=15m and y is the height of shear wall counted from the bottom of shear wall) to see the variation of vertical stress distribution with at these three different locations which is called the arch effect due to the span length and at the different depth of shear wall in shear wall-transfer beam system. These three levels are named as level S1, level S2 and level S3 respectively.

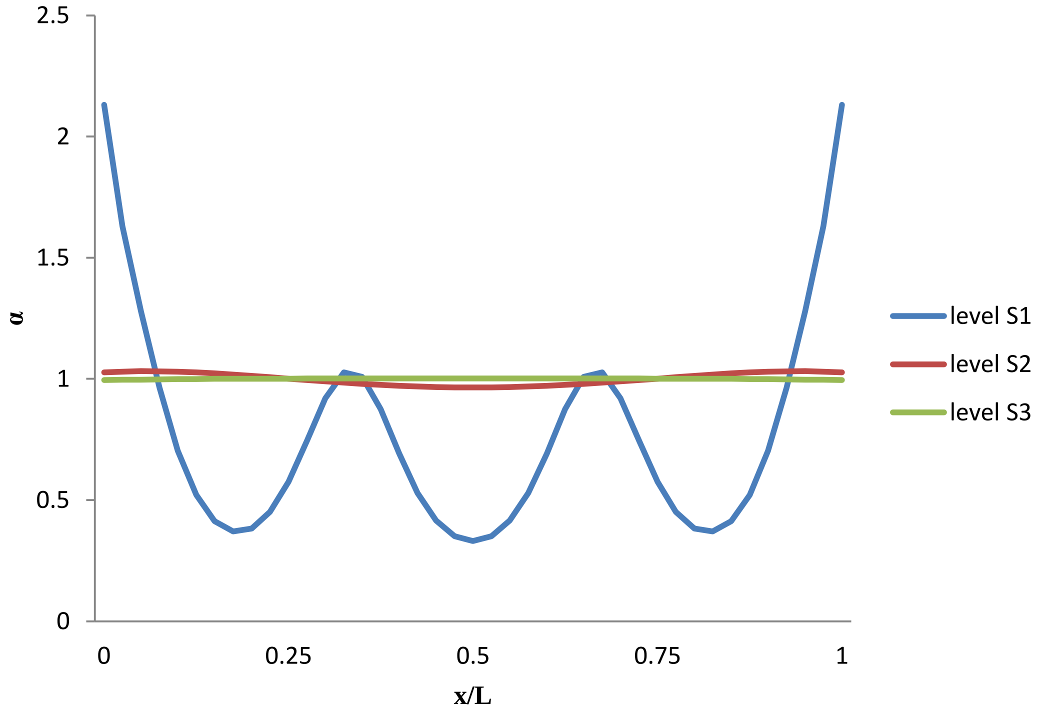
The variation of vertical stress distributions along the height of shear wall of these three models are shown in Fig. 3.2.



(a) Variation of vertical stress along the shear wall (Model B-1)



(b) Variation of vertical stress along the shear wall (Model B-2)



(c) Variation of vertical stress along the shear wall (Model B-3)

Figure 3.2 Vertical stress for set B models

For Fig. 3.2, it shows the vertical stress distribution of each model along the span. For the results of these three models shown in Fig. 3.2, the largest vertical stress occurs at the support of the end span. The smallest value of vertical stress occurs at each mid span of the model. For the interior support, the vertical stress goes up again but it is not very large compared to the end support. At the bottom of the shear wall, the vertical stress at interior support is even less than half of the vertical stress occurs at the end support.

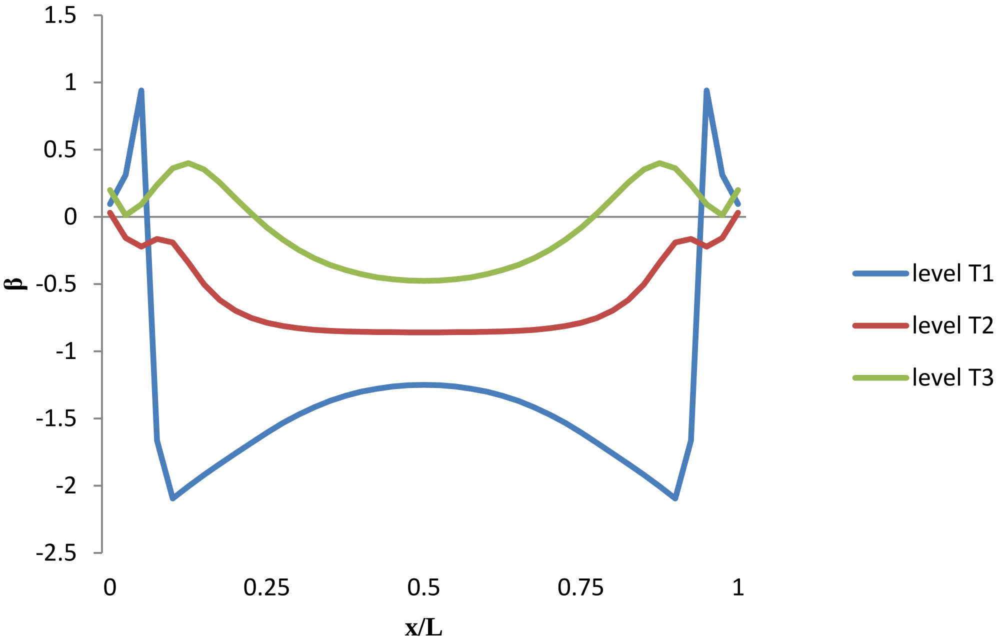
For the model B-1, the vertical stress at end support is 5 times of the applied pressure which is also the largest in these three models. As the length of span becomes shorter, the vertical stress at end support reduced. Moreover, for model B-1 the vertical stress becomes to zero at mid span but when the length of span becomes shorter, the vertical stress at mid span goes up. That means the arch effect reduced when the length of span becomes shorter. This can also be seen at the other level of shear wall. For model B-1, the arch effect at level S2 can also been seen. However, the arch effect almost disappears and the vertical stress tends to constant at that level for model B-2 and model B-3.

The present of the arch effect is because the stiffer region at the column support. When there is a column supporting a transfer beam, the column will provide a constraint to the transfer beam to reduce the vertical displacement, which means stiffer of that region as result and the vertical stress will becomes larger than those regions that no constraint. For the interior column, the vertical stress is less than the exterior column, which is because for the interior column, the left span and right span give an opposite moment to each other. Therefore, the vertical stress can be reduced due to the opposite moments. However, for the exterior column there is no another side of span to balance the vertical stress. As result, the larger vertical stress occurs at the exterior column.

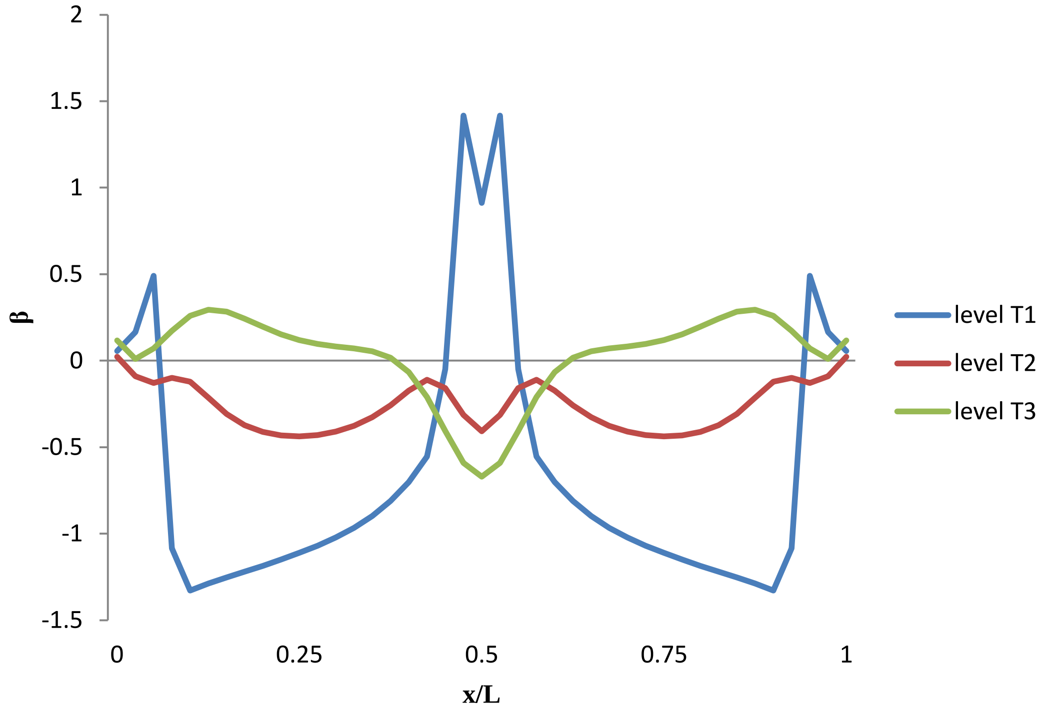
2. Horizontal stress

For the investigation of horizontal stress in shear wall, it is always in compression except the tensile zone which is likely a triangular area just above interior supports. However, for horizontal stress investigation, the interest of horizontal stress is more concentrate on the internal area of the transfer beam to see whether the transfer beam is designed as fully tension beam due to the effect of shear wall-transfer beam system or as an ordinary beam with the upper part subjected to compression and the lower part subjected to tension. In this section, for each model, there are three levels of depth of the transfer beam have been investigated where are the bottom level, middle level and the top level of the transfer beam named as level T1, level T2 and level T3 respectively. That is, the top surface, middle line and the bottom surface of transfer beam are investigated to show the variation of horizontal stress distribution with the different depth of the transfer beam.

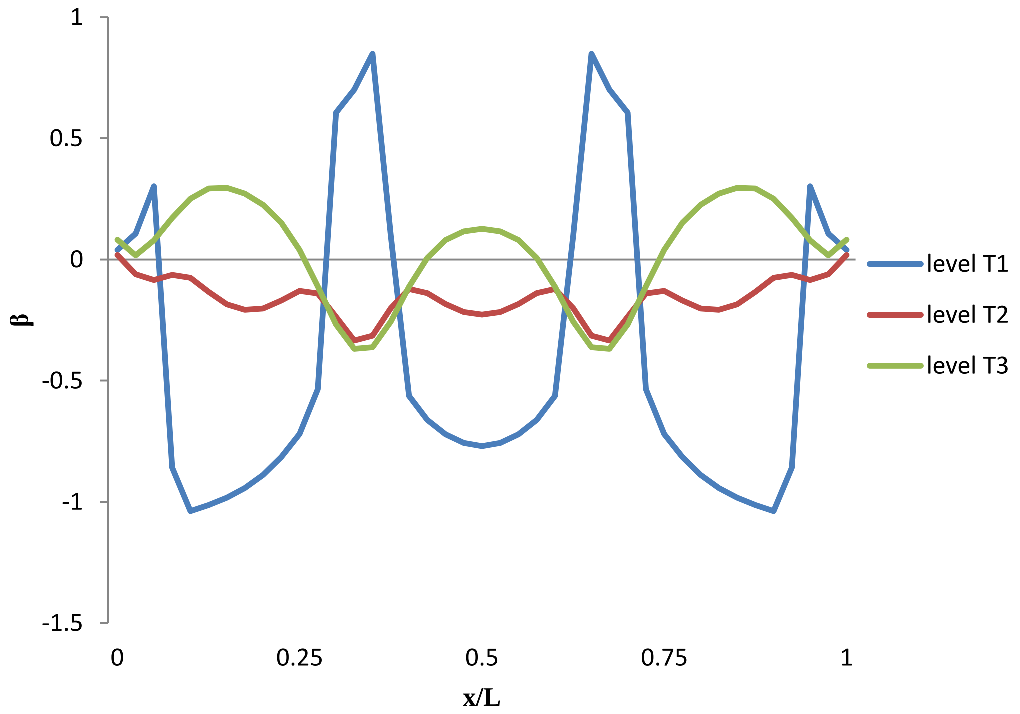
The variation of horizontal stress distributions along the different height of transfer beam of these three models are shown in Fig. 3.3.



(a) Variation of horizontal stress along the transfer beam (Model B-1)



(b) Variation of horizontal stress along the transfer beam (Model B-2)



(c) Variation of horizontal stress along the transfer beam (Model B-3)

Figure 3.3 Horizontal stress for set B models

Fig. 3.3 shows the horizontal stress distribution at different depth of transfer beam for different models. For both of these three models, the result shows that at the bottom level of the transfer beam, the horizontal stress distribution is in tension except at and near the exterior and interior support, where the horizontal stress is in compression. Besides, at this level the transfer beam subject the large variation of horizontal stress. Moreover, model B-2 and model B-3 shows that the horizontal stress at interior support is much larger than the horizontal stress at the end support. However, at the middle level of the transfer beam, the result shows that it is in fully tension stage which is unlike the normal beam. For the middle level of normal beam, it usually shows zero stress so call the neutral axis. At the top level of the transfer beam, the result shows that there are some portions of it still are in tension especially for model B-1.

The largest horizontal compression stress occurs at the interior support of bottom level of model B-2. However, the largest horizontal tension stress occurs at the bottom level of model B-1. Besides, for the top level of model B-2 and model B-3, the results show that the horizontal stress at mid span of transfer beam is subjected to tension but not for model B-1. The horizontal stress is still in tension at mid span of model B-1 at top level. Therefore, the neutral axis changes due to the importance of the length of span.

This effect is because the shear deflection is also counted into calculating the horizontal stress. For normal beam, there is an assumption that the shear deflection is zero. Therefore, the theory and formulas for normal beam is not useful in this situation because the stress will be govern by shear deflection if the beam is a deep beam. That means for a deep beam or transfer beam in the shear wall-transfer beam system, the theory and formulas for normal beam is no longer be available because the span/depth ratio of those kind of beam is much larger than normal beam. Therefore, the shear deflection effect will govern the total deflection of an element and the stress distribution.

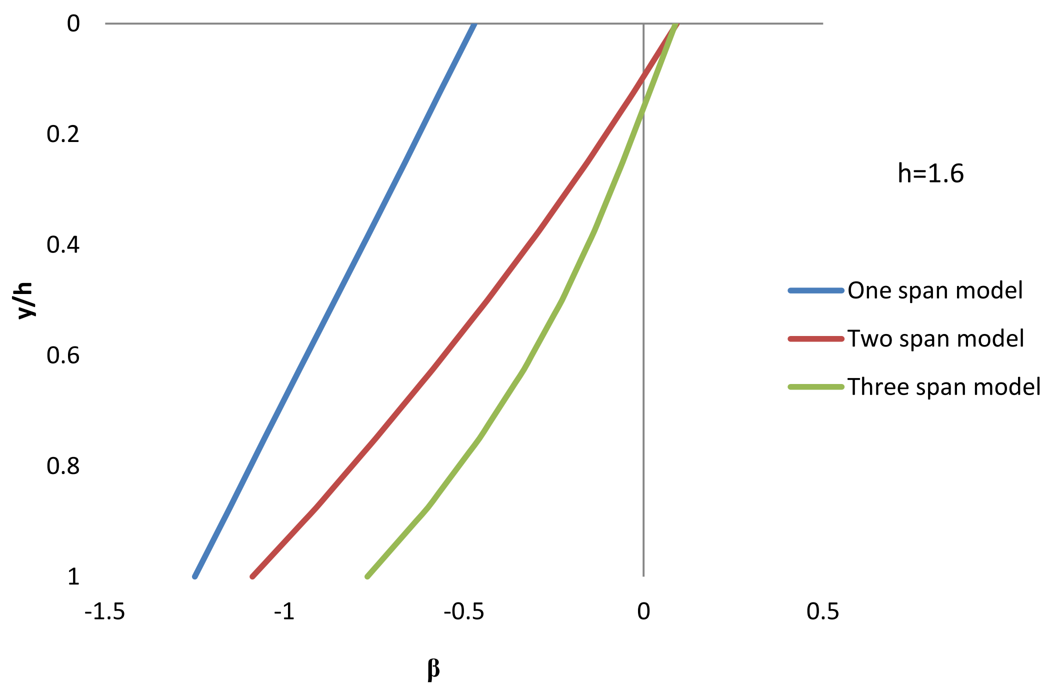


Figure 3.4 Horizontal stress along depth at mid span

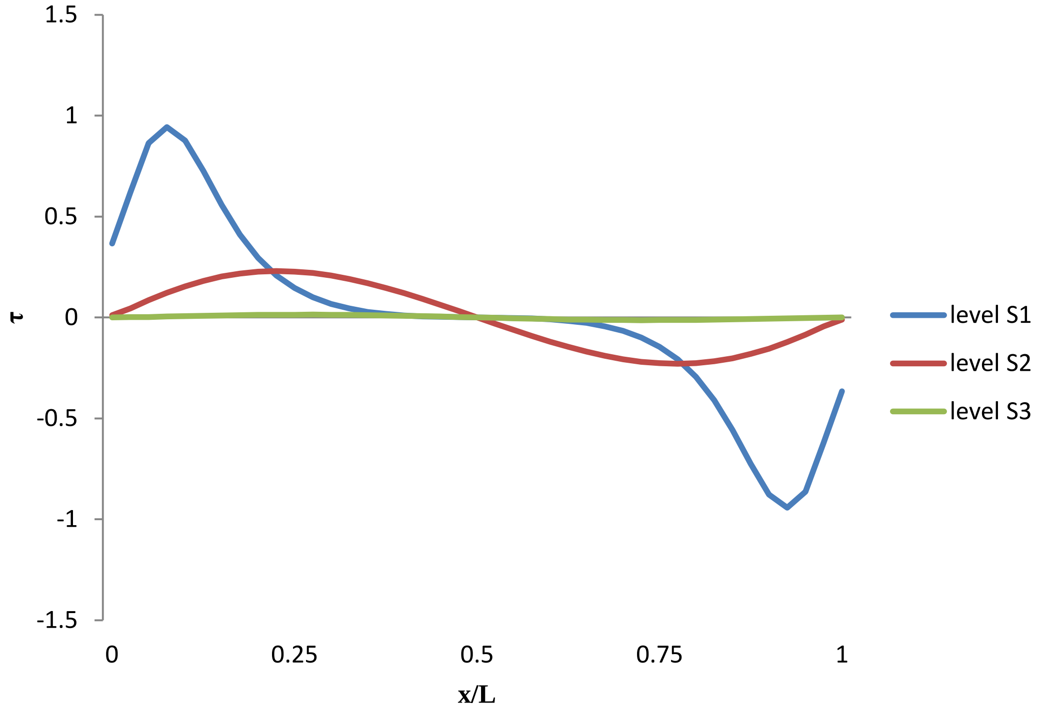
Fig. 3.4 shows the horizontal stress distribution along the depth of transfer beam at mid span for different models. For normal beam, the neutral axis is usually at the middle depth of the beam to separate the compression part and tension part of a beam. However, for the transfer beam in the shear wall-transfer beam system, the neutral axis goes up because the shear wall can be considered as a part of transfer beam. Therefore the neutral axis would move up due to this interaction between shear wall and transfer beam. For the result from one span model, the transfer beam is subjected to fully tension situation which means the neutral axis is even upper than the top of transfer beam and occurs in the shear wall. Moreover, the top reinforcement of the transfer beam must be also considered when it is in the design phrase. For the results from two and three span models, the neutral axis occurs within the transfer beam. However, the location of neutral axis is even much upper than normal beam. With the span of those models more which means the span/depth ratio is lower, the location of neutral axis becomes lower. The details of this behavior will be discussed in Chapter 4.

The present of the horizontal stress distribution curve is because the present of shear stress. It has to balance the three equilibrium equations for each element which means the shear stress and the horizontal stress are interacted with each other. To satisfy the vertical equilibrium, the shear stress must be toward to upper and the horizontal stress must be in tensile stress. Therefore, these two will induce the opposite moment considering the lower part of the element. As result, the larger shear stress will induce the larger horizontal tensile stress. The shear stress will be discussed more detail in following section.

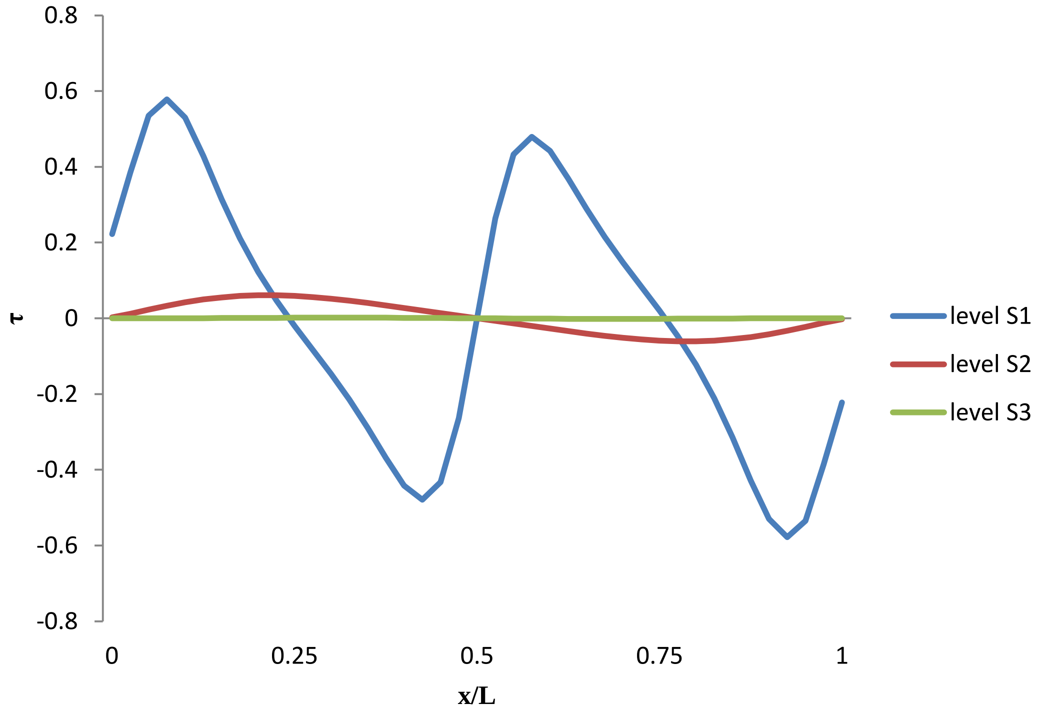
3. Shear stress

In this section, the shear stress distribution in the lower part of shear wall is investigated. Three different models have been investigated and for each model, the data of shear stress have taken from three horizontal sections where are y/L=0, y/L=0.5 and y/L=1 (L is the span length of the model, in these three models, L=15m and y is the height of shear wall counted from the bottom of shear wall) to see the variation of shear stress distribution at these three different locations. Those levels are the same as the levels investigated for vertical stress.

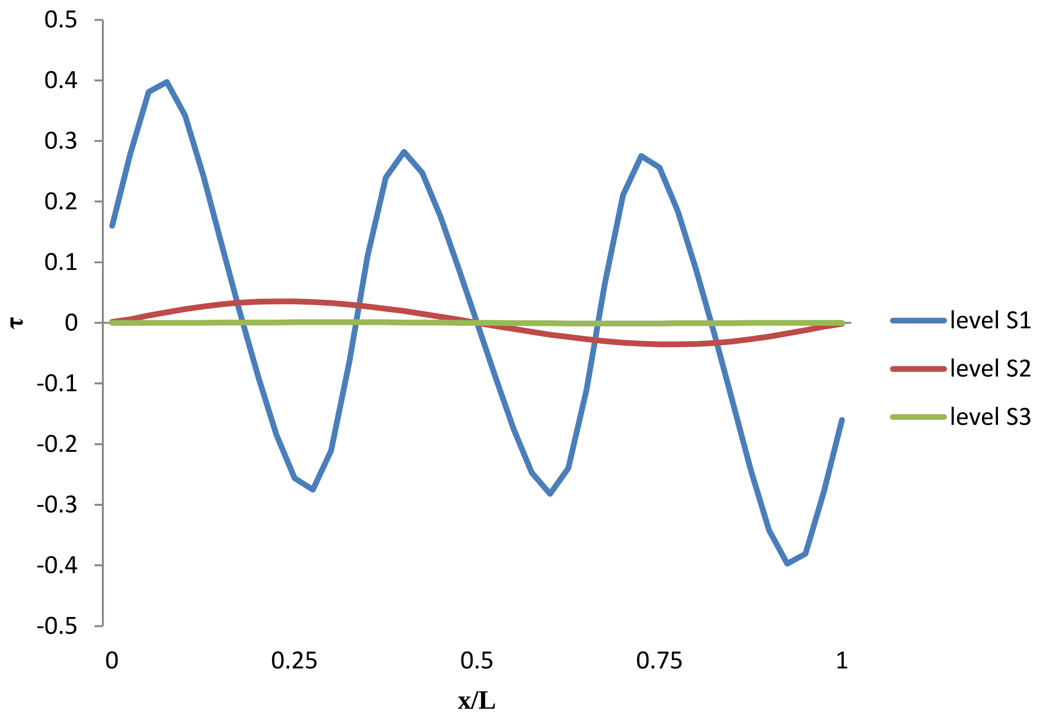
The variation of shear stress distributions along the height of shear wall of these three models are shown in Fig. 3.5.



(a) Variation of shear stress along the shear wall (Model B-1)



(b) Variation of shear stress along the shear wall (Model B-2)



(c) Variation of shear stress along the shear wall (Model B-3)

Figure 3.5 Shear stress for set B models

Fig. 3.5 shows the shear stress distribution for three different models at different location in the lower part of shear wall. For both of these models, the shear stress distribution at the level S3 is zero that means no shear effect at or above this level which is the same as the vertical stress part. With the location becomes lower, the shear stress distribution becomes a curve as like those curves at location of level S2 shown in the figure. At this level the shape of shear stress distribution for these models is most likely the same. However, at the location of level S1, the shear stress distribution becomes different for these three models due to the effect of number of span.

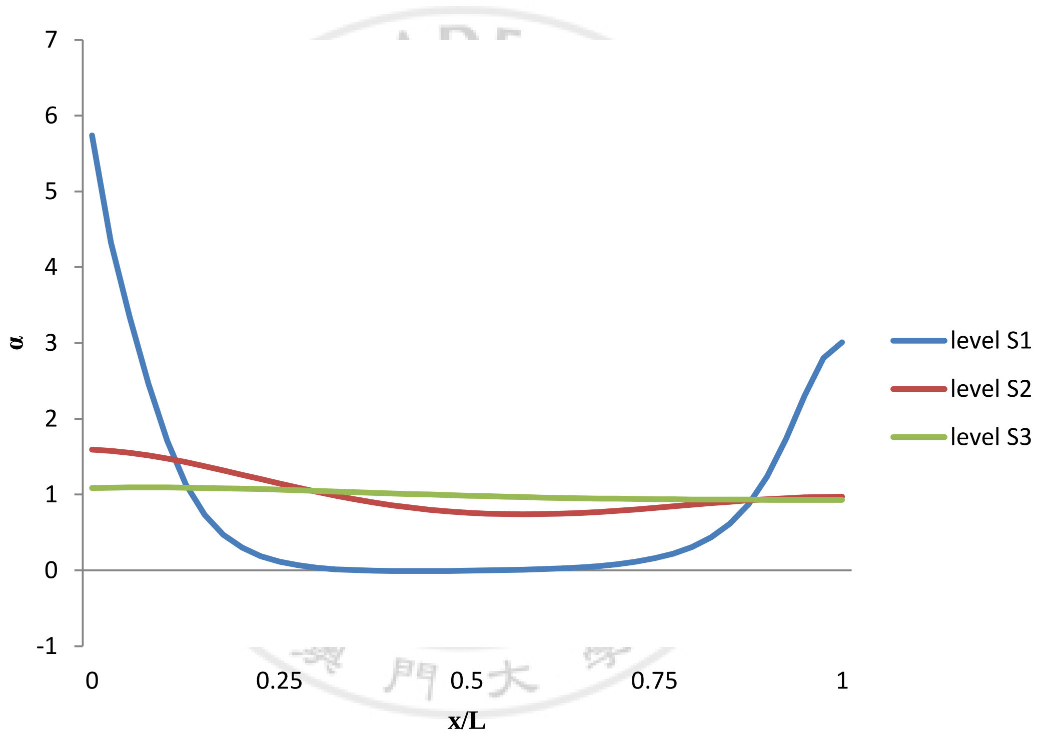
In the model B-1 there is a region that the shear stress tends to zero which is near the mid span. However, for model B-2 and model B-3, the span length is shorter therefore this effect becomes a point but not a region. Moreover, those interior columns affect the shear stress raise up again so that the shear stress increase rapidly again.

3.3.2 Constant span length

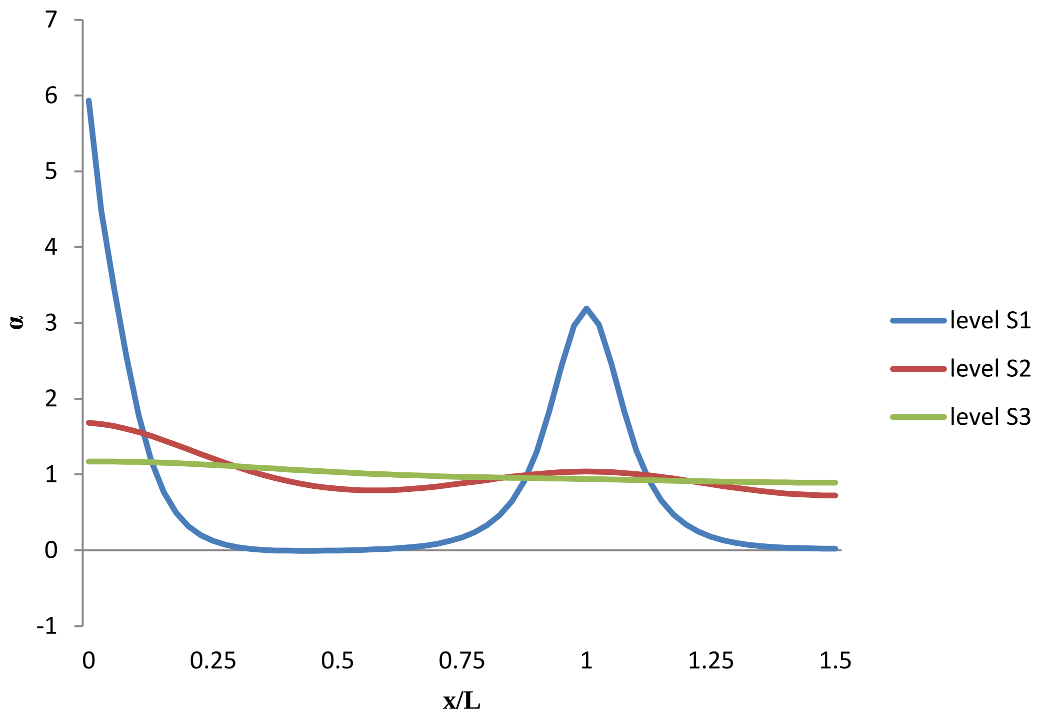
In this section, the length for each span is fixed as 15m. For one span model, the total length of model is 15m which is the same as the model in section 2.3.1. Therefore, one span model will not be investigated again in this section. For two and three span model, the overall total length is 30m and 45m, respectively. In this section, the investigation method is exact the same as Section 3.3.1 but the dimension of models is different to see effect of stresses when the length of each span become longer. The length of span for these two models are shown in Table 3.1 and the other dimensions for each partitions of models are the same as those models discussed in Section 3.3.1. In this section, the models name as set C.

1. Vertical stress

In this section, the vertical stress distribution in the lower part of shear wall is investigated with the same span length. The two models shown in Fig. 3.1(b) and Fig. 3.1(c) have been investigated. The variation of vertical stress distribution for two models along the length of shear wall is shown in Fig. 3-6.



(a) Variation of vertical stress along the shear wall (Model C-1)



(b) Variation of vertical stress along the shear wall (Model C-2)

Figure 3.6 Vertical stress for set C models

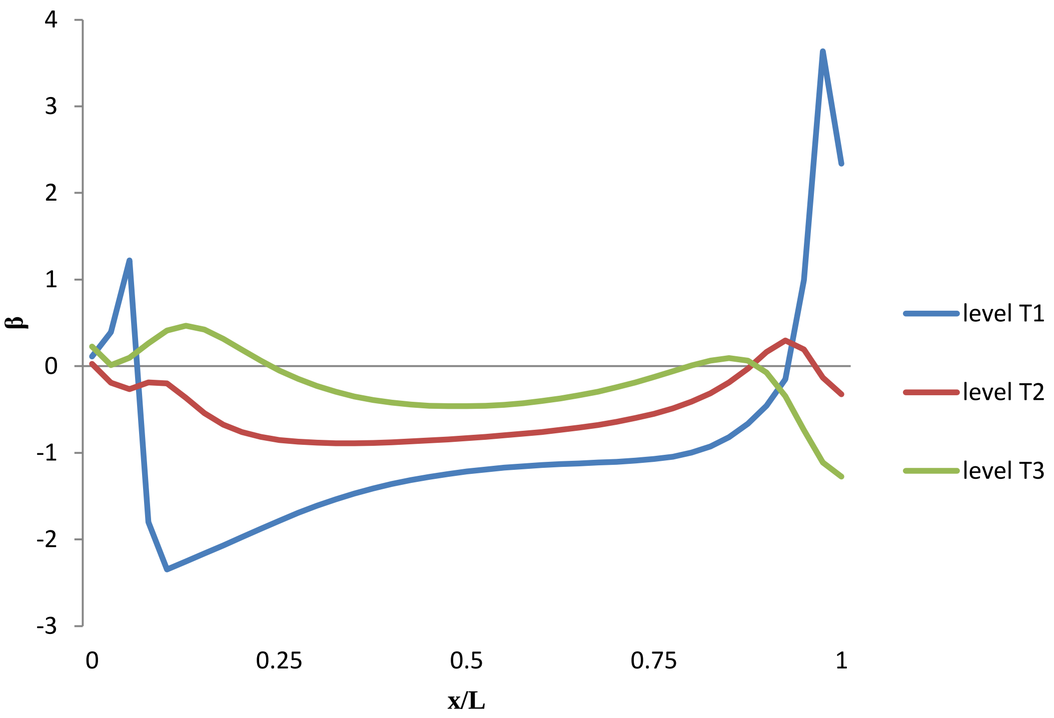
For the two span model, the vertical stress distribution is shown in Fig. 3.6(a). The vertical stress distribution is just shown the half of the models because of the symmetric of the model. Compare with Fig. 3.2(b) which shows the result obtained from two span model in Section 3.3.1, the trend of the variation of the vertical stress distribution is not much different. However, the vertical stress is approximately equal to zero near the mid span for Fig. 3.6(a) which is because the length of span is longer. Therefore, the arch effect becomes more significant and most of stress transferred at the two columns support.

The vertical stress parameter α, which can shows the ratio of vertical stress and the in-plane load applied on the top of the shear wall, Compare with two results from Fig. 3.2(b) and Fig. 3.6(a), the α at the exterior and interior column support for the span length fixed model is almost double to that obtained from total length fixed. Which means with the same thickness of shear wall and in-plane distributed load, the vertical stress at exterior and interior columns for the span length fixed model is almost double to the total length fixed model.

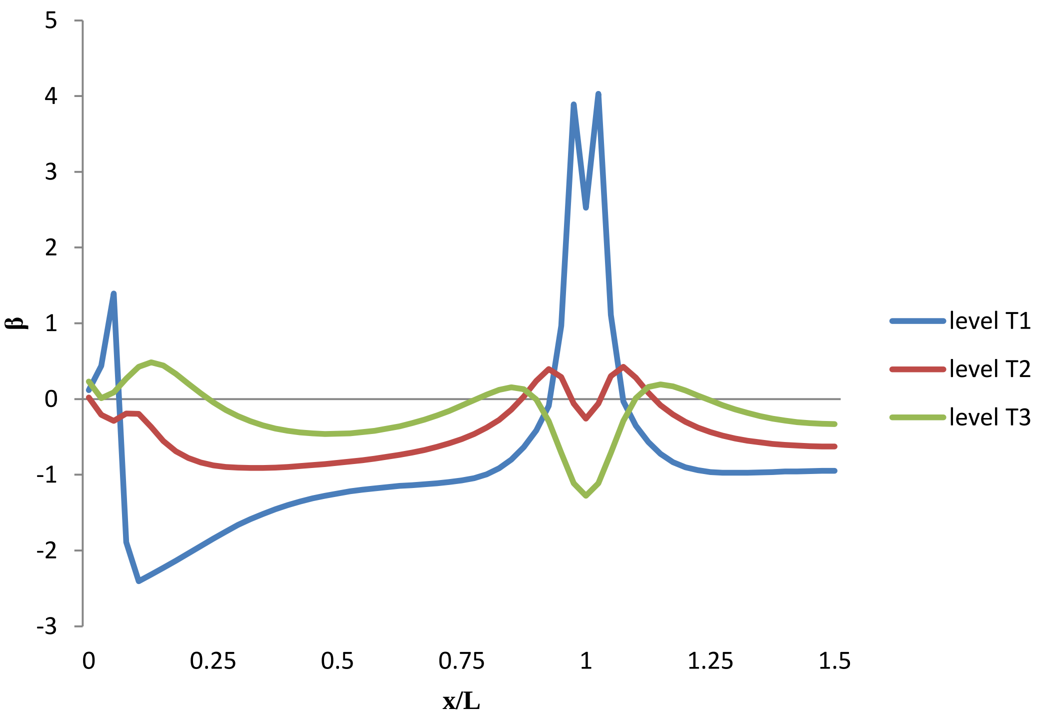
The results from three span models are shown in Fig. 3.6(b). The difference between these two models is similar to the two span models in Fig 3.2(c). However, the variation of vertical stress at exterior and interior support for three span models becomes larger than the two span models.

2. Horizontal stress

For the investigation of horizontal stress, the transfer beam is investigated to see the tensile stress along the span length. The investigation method is also the same as Section 3.3.1. The horizontal stress distributions for the two models are shown in below.



(a) Variation of horizontal stress along the transfer beam (Model C-1)



(b) Variation of horizontal stress along the transfer beam (Model C-2)

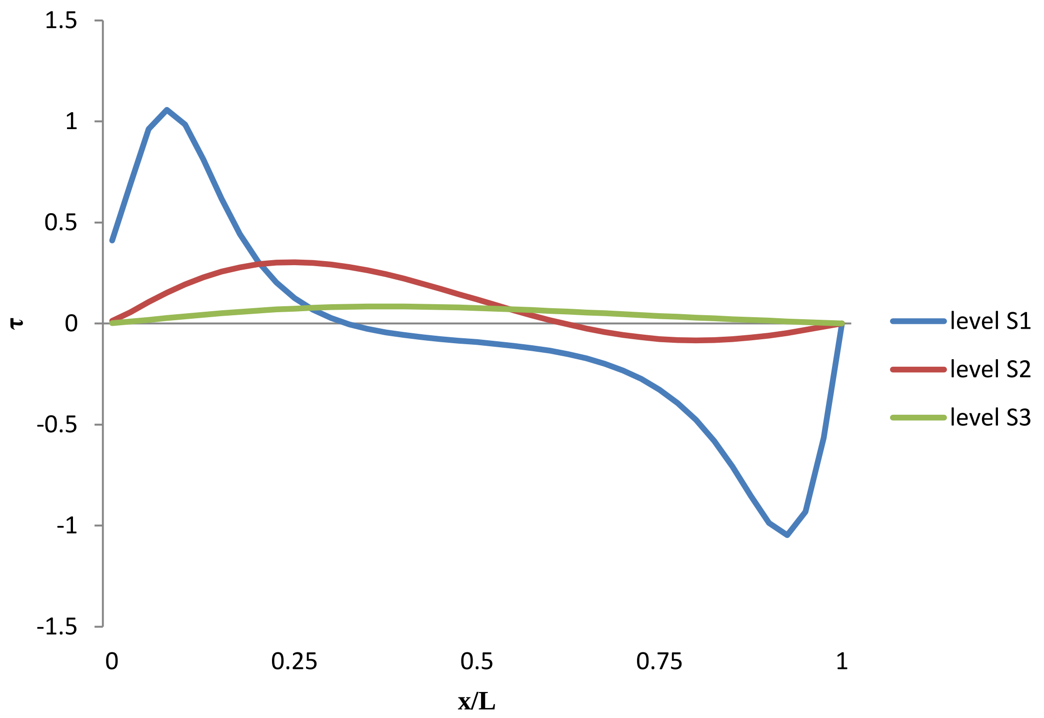
Figure 3.7 Horizontal stress for set C models

Fig. 3.7 shows the horizontal stress distribution at different levels of transfer beam for two span and three span models. The horizontal stress distribution is just shown the half of models because of symmetric of models. Compare the results of Fig. 3.7(a) and Fig. 3.3(b), which is both two span cases, the trend of horizontal stress distribution is similar. However, the horizontal stress at the bottom of transfer beam in Fig. 3.7(a) is more than double of Fig. 3.3(b). Besides, Fig. 3.7(a) shows most of the part of transfer beam is subjected a tensile force even at the top of the transfer beam except the part near supports. It can say that this transfer beam is a fully tension beam due to the large span length. This is different from the result obtained from Fig. 3.3(c), which shows the horizontal stress at the top of transfer beam is positive that means at that location, the transfer beam is subjected a compressive force.

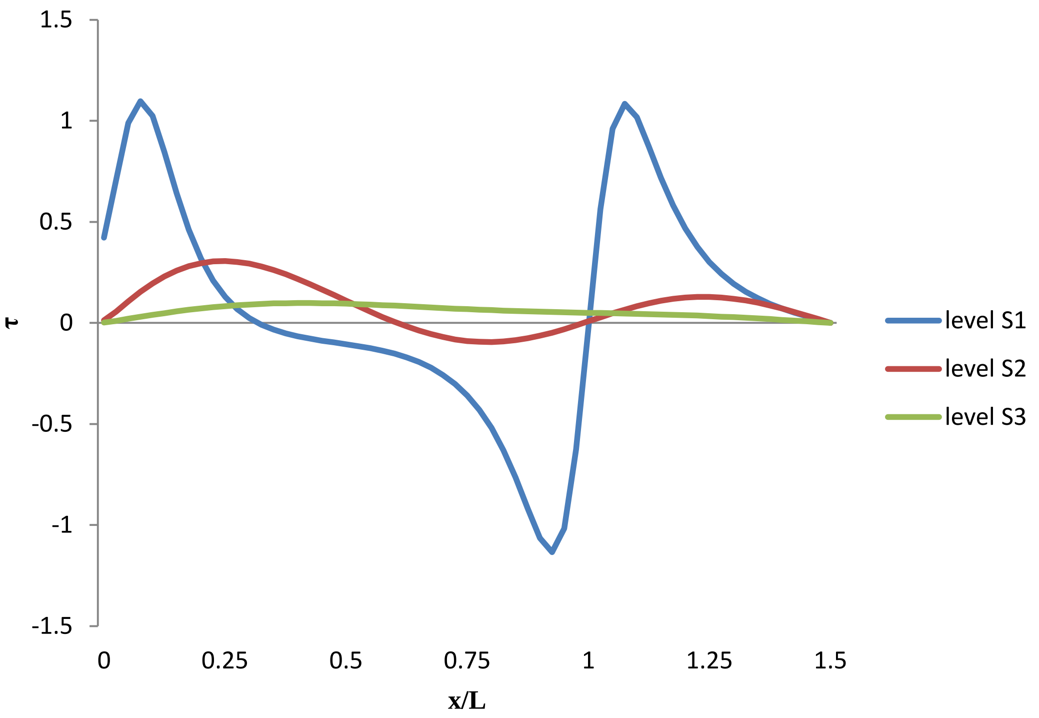
The horizontal stress at the bottom of transfer beam in Fig. 3.7(b) is much larger than horizontal stress in Fig. 3.3(c). Besides, the transfer beam in Fig. 3.7(b) is a fully tension beam.

3. Shear stress

For the shear stress investigation, the lower part of shear wall is investigated. The investigation method for shear stress is also the same as the method used in Section 3.3.1. Fig. 3.8 shows the shear stress distribution at different levels for the lower parts of shear wall for set C models.



(a) Variation of shear stress along shear wall (Model C-1)



(b) Variation of horizontal stress along shear wall (Model C-2)

Figure 3.8 Shear stress for set C models

The shear stress distributions in Fig. 3.8 are also just shown the half of models due to symmetric. Compare with the shear stress distribution in Fig. 3.8 and Fig. 3.5, the shear stress obtained from Fig. 3.8(a) is also large than the shear stress obtained from Fig. 3-5(b). Besides, the shear stress distribution at the bottom of shear wall in Fig. 3.8(a) shows there are two inflection points. Between these two inflection points, the shear stress decrease slowly where is near the mid span of transfer beam. Moreover, the shear stress is very small near mid-span. This is different from the shear stress distribution at the bottom of shear wall in Fig. 3.5(b) which is because there is no inflection point for the shear stress distribution near the mid span in Fig. 3.5(b). Therefore, the shear stress decreases rapidly even near the mid span of model. For the shear stress at the level S1 in Fig. 3.8(a), there is still some shear stress near the mid span. However, the shear stress at that location is small. Besides, the trend of shear stress distribution at the level S2 is also similar compare to the results from Fig. 3.8(a) and Fig. 3.5(b).

The shear stress distribution shown in Fig. 3.8(b) Fig. 3.5(c), there are also similar to the two span cases.

2.3 Summary

In this Chapter, the effect of structural behavior on a shear wall-transfer beam system due to span which including the number of span and the length of span is investigated. The variation of stresses distribution in a shear wall-transfer beam system can show the structural behavior. Therefore, the vertical stress and shear stress in the lower part of shear wall and the horizontal stress in the transfer beam at different levels are taken out from different models and compared the changes due to different conditions in this Chapter.

1. Vertical stress

For vertical stress at the lower part of shear wall in a shear wall-transfer beam system, the main investigating direction is the arch effect behavior which is the behavior that the vertical stress near the mid span of the model would transmit to the two supporting columns. Because of this effect, the vertical stress near mid span becomes small and the vertical stress at the two supporting columns become large. The results show that the significance of arch effect depends on two factors which are the number of span and the length of span.

The number of arch depends on the number of span. If there is one span model, there is only one arch for the vertical stress and so on. Besides, the vertical stress at the exterior column is much larger than the vertical stress at the interior column.

On the other side, the length of span decides the shape of arch. If the length of span is long enough, the vertical stress near mid span would transmit to the two nearest columns and tends to zero. That means the larger length of span, the larger vertical stress at two columns as result when all other factors are in the same scenario. However, if the length of span is short, the vertical stress would increase quickly from the mid span. That results a less vertical stress at the two columns because those vertical stress near mid span has no enough space to transmit to two columns. Therefore, some of vertical stress would stay near mid span.

2. Horizontal stress

For the horizontal stress at transfer beam in a shear wall-transfer beam system, the stress shows the structural behavior of transfer beam whether it subjects a tensile stress or compression stress. In this Chapter, the effect of horizontal stress due to number of span and length of span are investigated. Besides, the non-linear effect on horizontal stress in transfer beam is shown. However, this effect is more related to span/depth ratio. Therefore, the more details for this effect will be discussed in Chapter 4.

From the results shown in this Chapter, at the level T1, the horizontal stress increase and become positive rapidly at the regions where there are column supports. That means the horizontal stress changes from tensile stress to compressive stress rapidly near the column support. However, this effect reverses for the level T2 and level T3. From this result, it can say that more the number of span would result more curves in the horizontal stress distribution. Besides, the horizontal stress at interior column support is much larger than the horizontal stress at exterior column.

Meanwhile, the shape of horizontal stress distribution near mid span is controlled by the length of span. If the length of span is long enough, the horizontal stress distribution near mid span would become more flat as result.

3. Shear stress

For the shear stress at the lower part of shear wall in a shear wall-transfer beam system, the two factors which are number of span and length of span are investigated that how would affect the structural behavior in a shear wall-transfer beam system.

From the results in this Chapter, the shear stress distribution would pass through the zero point when there is an interior column. Besides, at the level S1, the shear stress increases rapidly if there is a column support. This is the effect that affect by the number of span. However, for the other levels in the lower part of shear wall, this conclusion is not available.

On the other hand, the length of span controls the shape of shear stress distribution near mid span. At the level S1, there are two inflection points near mid span when the length of span is long enough. Between these two inflection points, the shear stress distribution becomes less variation and the shear stress close to zero. However, these two inflection points become closer when the length of span becomes shorter.

CHAPTER 4 EFFECT OF SPAN/DEPTH RATIO

4.1 Introduction

Besides of the structural behavior of shear wall-transfer beam system due to number of span and span length, the other main factor that would affect the structural behavior of shear wall-transfer beam system is the span/depth ratio. In this Chapter, the effect of stress distribution due to different span/depth ratio will be investigated. Usually the transfer beam in shear wall-transfer beam system is much deeper than normal beam therefore the transfer beam can sustain the high moment and shear force induced by heavy load which included the self weight of shear wall and the load adding on the shear wall.

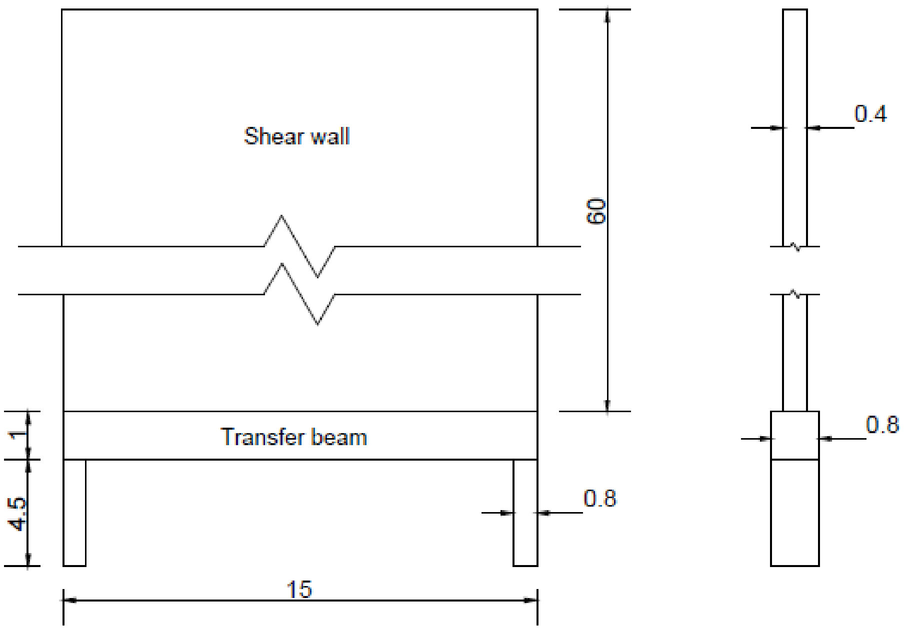
In this Chapter, two sets of model, which are constructed to investigate the effect of structural behavior due to span/depth ratio, name as set D and E. Each set of model contains three models which are one span shear wall-transfer beam structures but with different span/depth ratio. Another set of model contains also three models which are two span shear wall-transfer beam structures but with different span/depth ratio.

These two sets of models are simulated when the top of shear wall subject an in-plane pressure P toward to transfer beam where P equal to $100kN/m^2$. Therefore, with the thickness of shear wall 0.4m, the distributed in-plane load equal to 40kN/m.

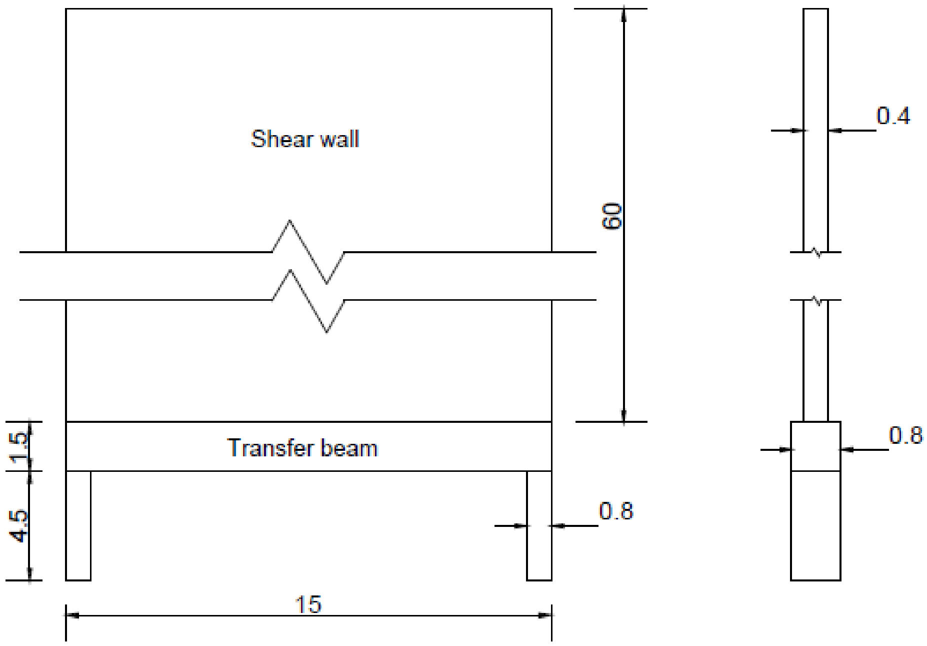
For this six models, the length of span is fixed but with different depth of transfer beam to change the span/depth ratio. Table 4.1 shows the span/depth ratio for these models. Fig. 4.1 and Fig. 4.2 show the geometry of all models.

Table 4.1 Span/depth ratio for models

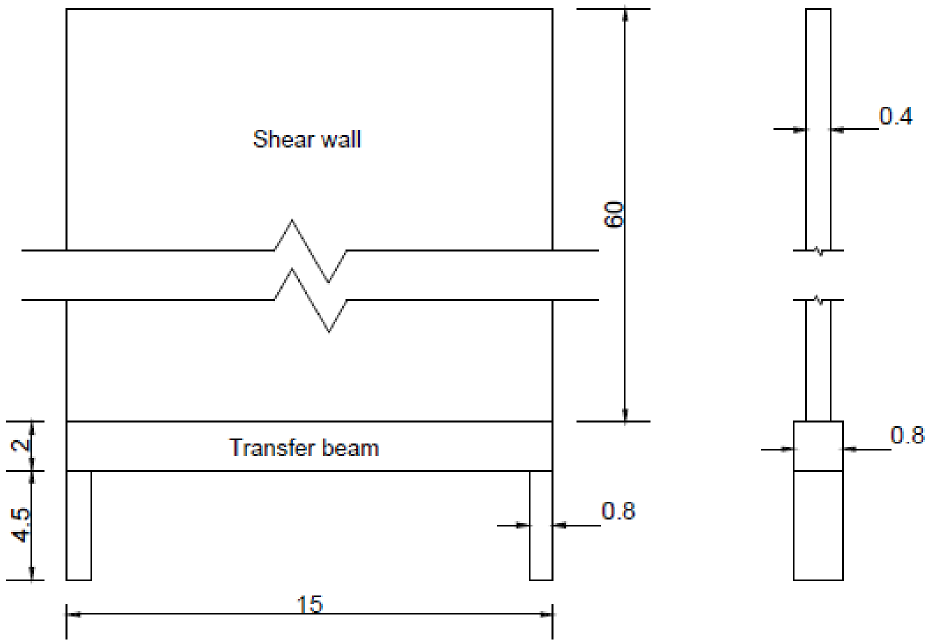
	Span/depth ratio	
	One span	Two span
Model 1	15	15
Model 2	10	10
Model 3	7.5	7.5



(a) Model with one span (Model D-1)

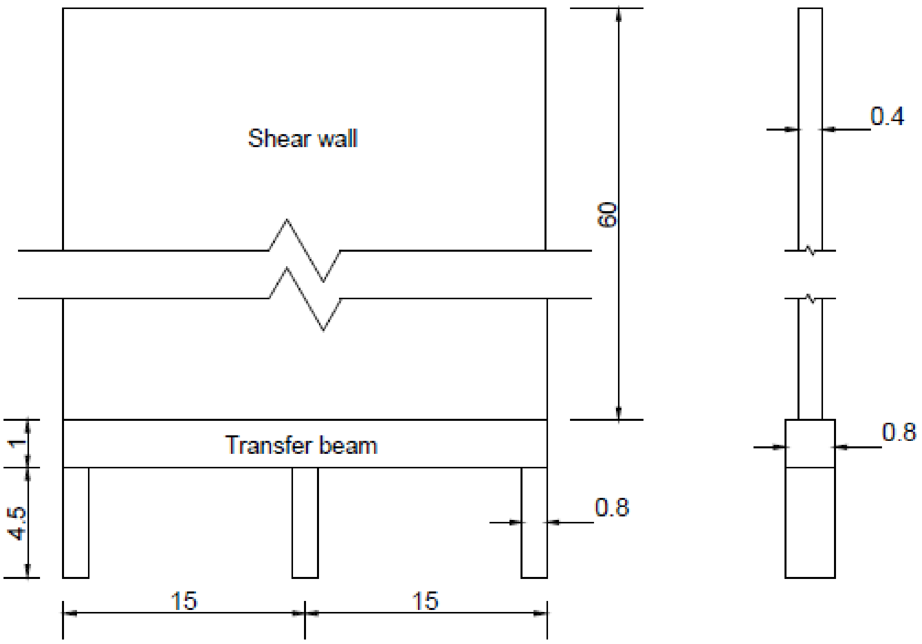


(b) Model with one span (Model D-2)

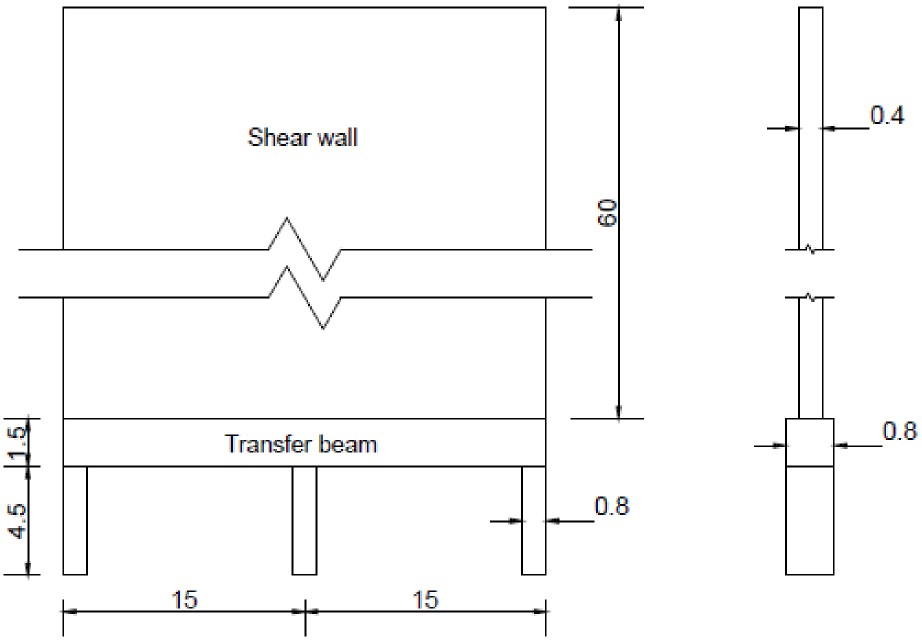


(c) Model with one span (Model D-3)

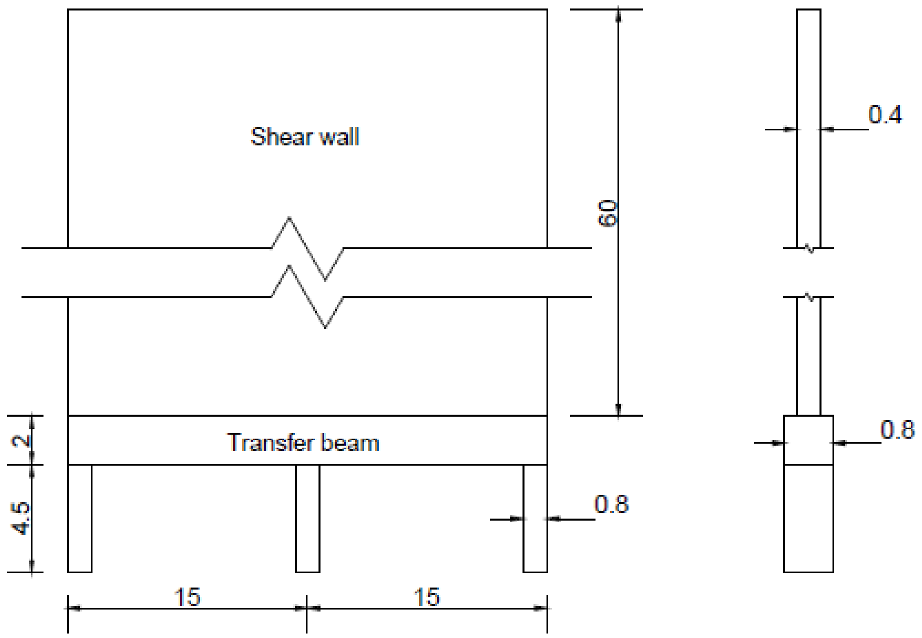
Figure 4.1 One span models with span/depth ratios



(a) Model with two span (Model E-1)



(b) Model with two span (Model E-2)



(c) Model with two span (Model E-3)

Figure 4.2 Two span models with span/depth ratios

4.2 Structural behavior

The investigation method in this Chapter is similar to the investigation method in Chapter 3. However, the investigation factor is not the same. The main difference between a normal beam and deep transfer beam is that the shear effect is very small for a normal beam. Therefore, the shear strain is ignored in simulate the structural behavior for a normal beam and the main factor for total strain is bending. However, a beam becomes deeper, the shear effect becomes larger and the bending effect becomes not the main factor for total strain but shear effect. For a transfer beam in shear wall-transfer beam system, the beam is usually very deep because the transfer beam is supporting a high vertical loading which including the self weight of shear wall and the loading on each floor. Thus, the shear effect must be taken account in simulating a transfer beam in shear wall-transfer beam system.

From the results in Chapter 3, it shows that the vertical stress and shear stress at the top of lower part of shear wall becomes constant and zero, respectively. Therefore, the vertical stress and shear stress will not be investigated at the level S3 in this Chapter. The vertical stress and shear stress will be investigated at the level S1 and level S2. Besides, the horizontal stress will be investigated at three levels which are level T1, level T2 and level T3.

4.3 Results and analysis

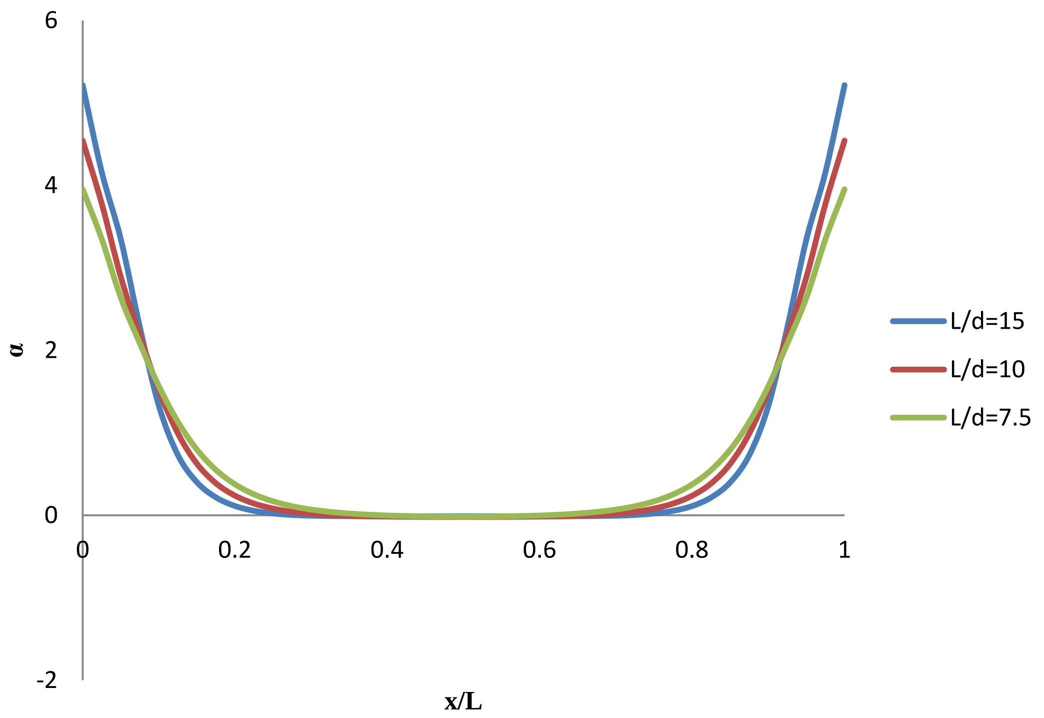
The set of models will be investigated and compare the results with different span/depth ratio. The set of models will be separated in to two parts, one span models and two span models for investigation. For each part, three stresses which including vertical stress, horizontal stress and shear stress will be investigated and for each stress. For vertical stress and shear stress in the lower part of shear wall, two levels of that partition will be investigated and for horizontal stress in the transfer beam, three levels will be investigated.

4.3.1 One span models

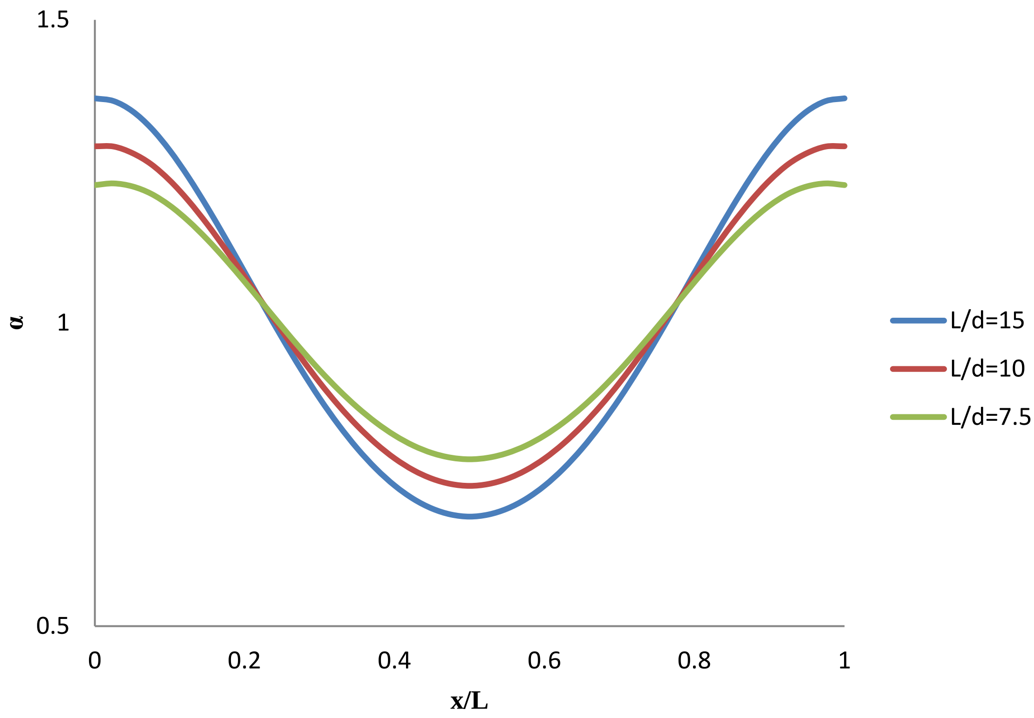
For one span investigation, there are three models that would be investigated to compare the variation of stresses due to different span/depth ratio.

1. Vertical stress

Below shows the vertical stress distribution for three different models at level S1 and level S2.



(a) Variation of vertical stress at level S1



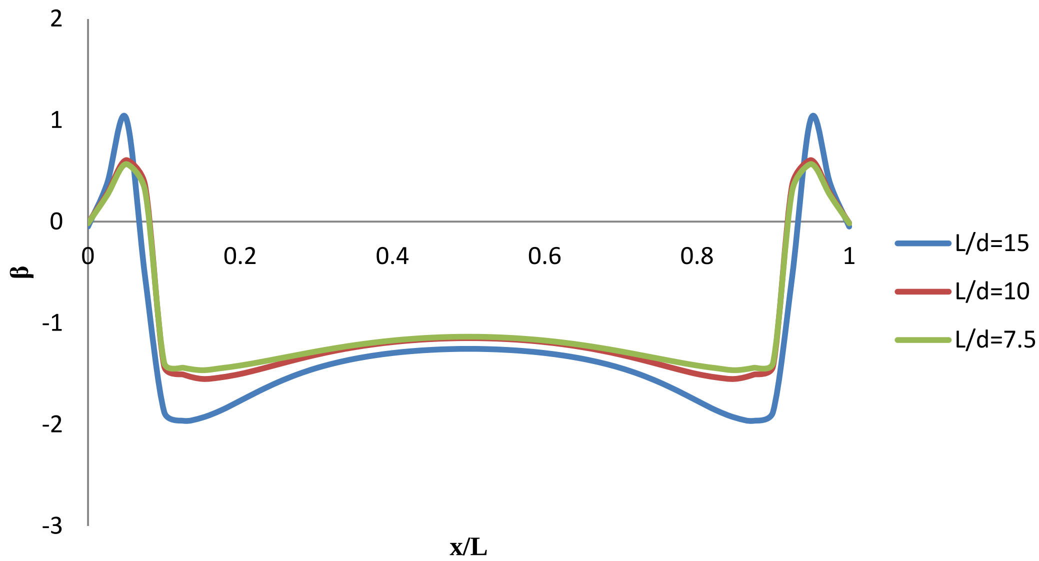
(b) Variation of vertical stress at level S2

Figure 4.3 Vertical stress for set D models

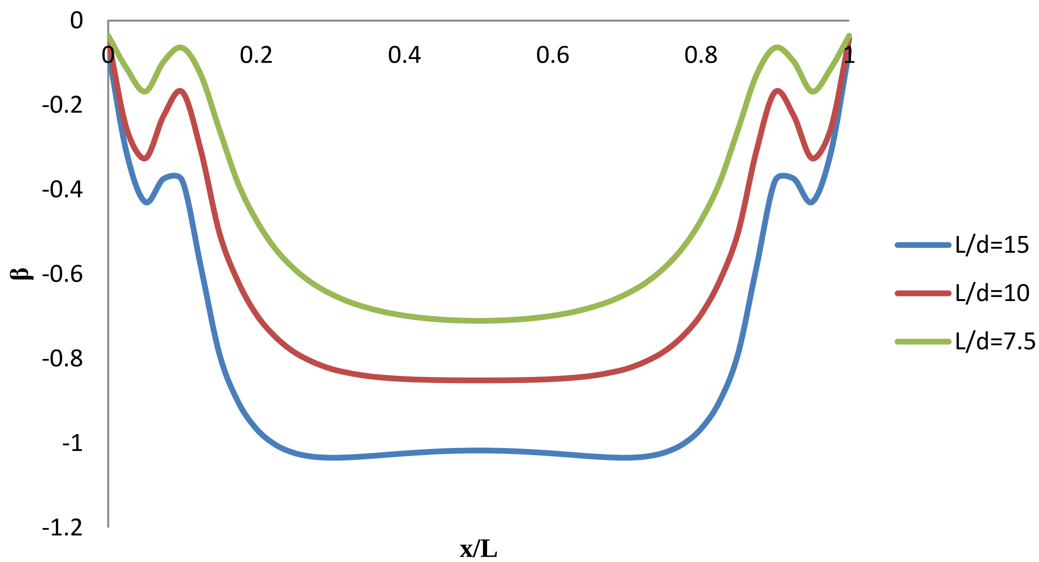
Fig. 4.3 shows the vertical stress distribution at different levels for three one span models with different span/depth ratio. Fig. 4.3(a) shows that at the column support, the vertical stress becomes larger when the span/depth ratio becomes larger. However, the vertical stress drops quicker if the span/depth ratio becomes larger. Therefore, Model 1 which has the larger span/depth ratio results the larger vertical stress at the column support but the vertical stress from model 3 exceed the vertical stress from model 1 quickly when there is no column support. Nevertheless, the vertical stresses from three models tend to zero near mid span. That is because the length of span is long and the arch effect for these models become significant. In order to compare the variation of vertical stress near mid span, the vertical stress distribution at level S2 for three models is shown in Fig. 4.3(b). From the results in Fig. 4.3(b), the trend of vertical stress distribution for three models is almost the same as the results from Fig. 4.3(a) except near the mid span. The arch effect for vertical stress at level S2 is much less then at level S1. Therefore, the decrement of vertical stress is not fast for three models. Besides, the larger span/depth ratio results the larger vertical stress at mid span.

2. Horizontal stress

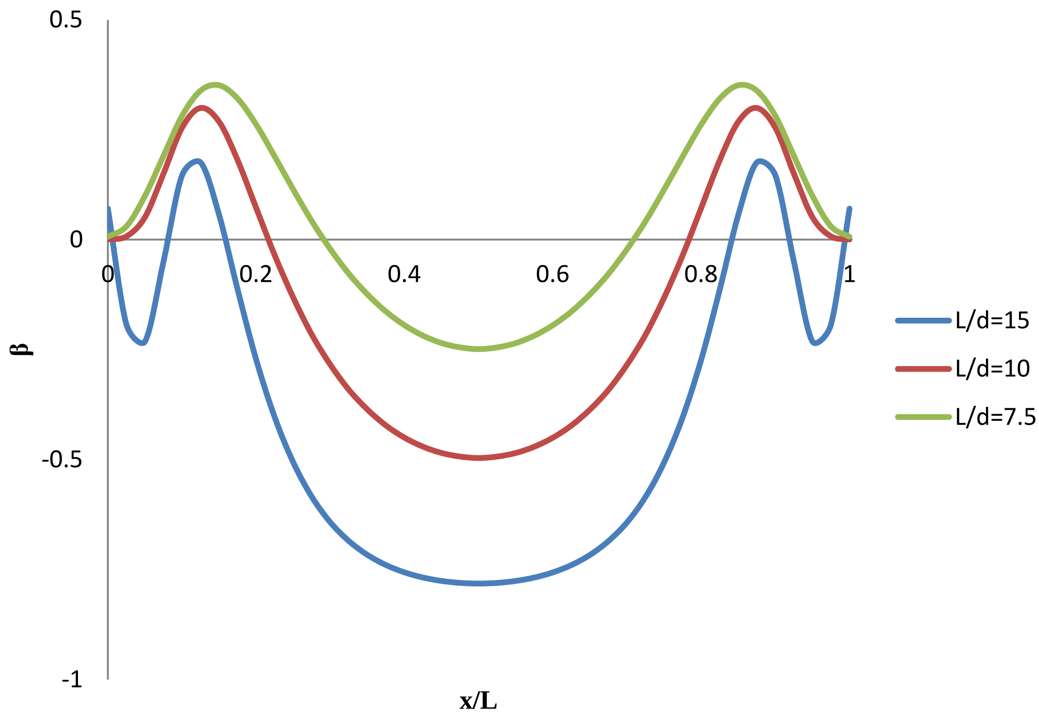
Below shows the horizontal stress distribution for three different models at level T1, level T2 and level T3.



(a) Variation of horizontal stress at level T1



(b) Variation of horizontal stress at level T2



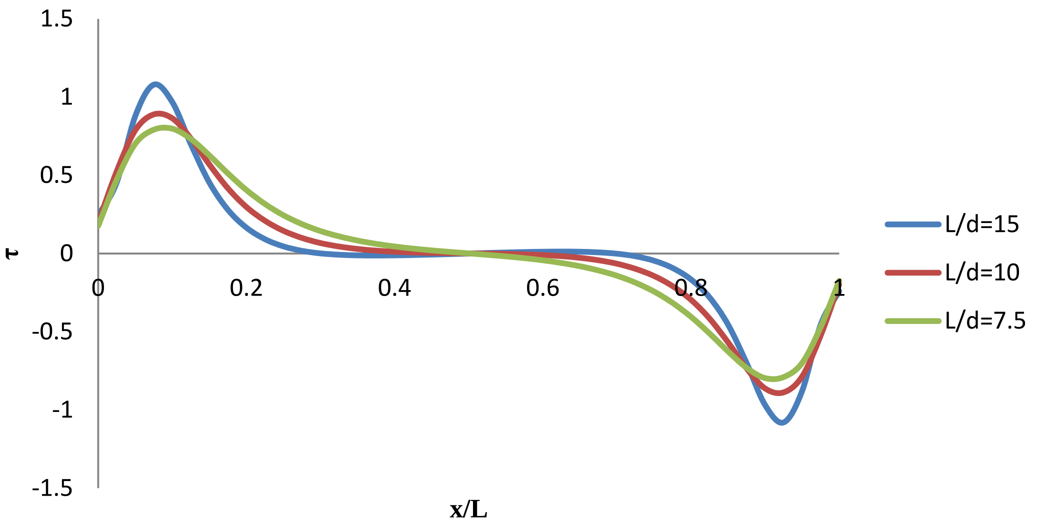
(c) Variation of horizontal stress at level T3

Figure 4.4 Horizontal stress for set D models

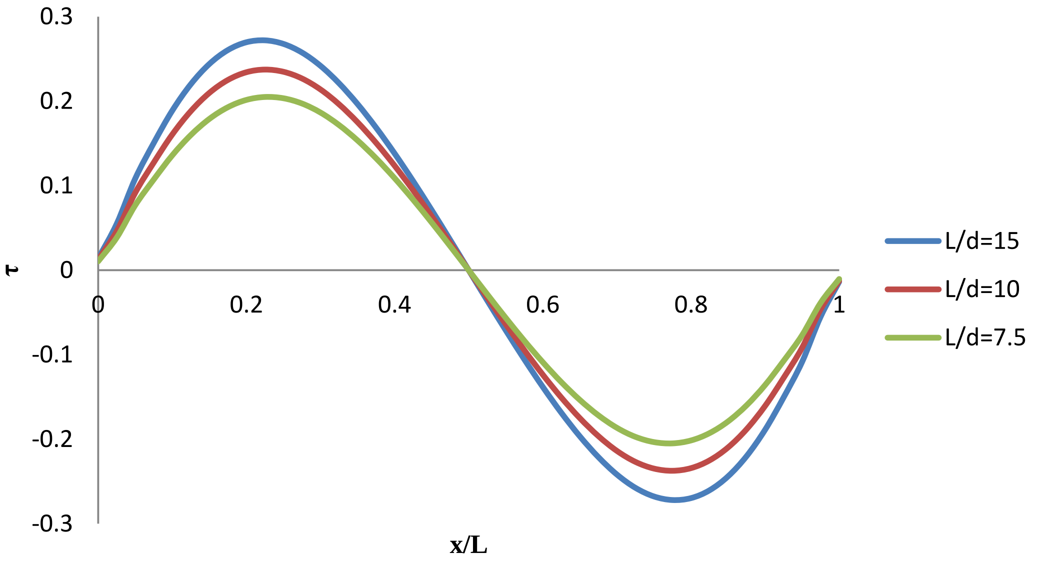
Fig. 4.4 shows the horizontal stress distribution for different models at level T1, level T2 and level T3 respectively. It is observed that the larger span/depth ratio which would result the larger horizontal tensile stress in most part of transfer beam. Fig. 4.4(c) shows the horizontal stress at the top of the beam is in compression if the span/depth ratio is not large. However, the transfer beam can be said that which is a fully tension beam when the span/depth ratio is large because the horizontal stress distribution at the top of beam shown in Fig. 4.4(c) is in tension at most part of the beam.

3. Shear stress

Below shows the Shear stress distribution for three different models at level S1 and level S2.



(a) Variation of shear stress at level S1



(a) Variation of shear stress at level S2

Figure 4.5 Shear stress for set D models

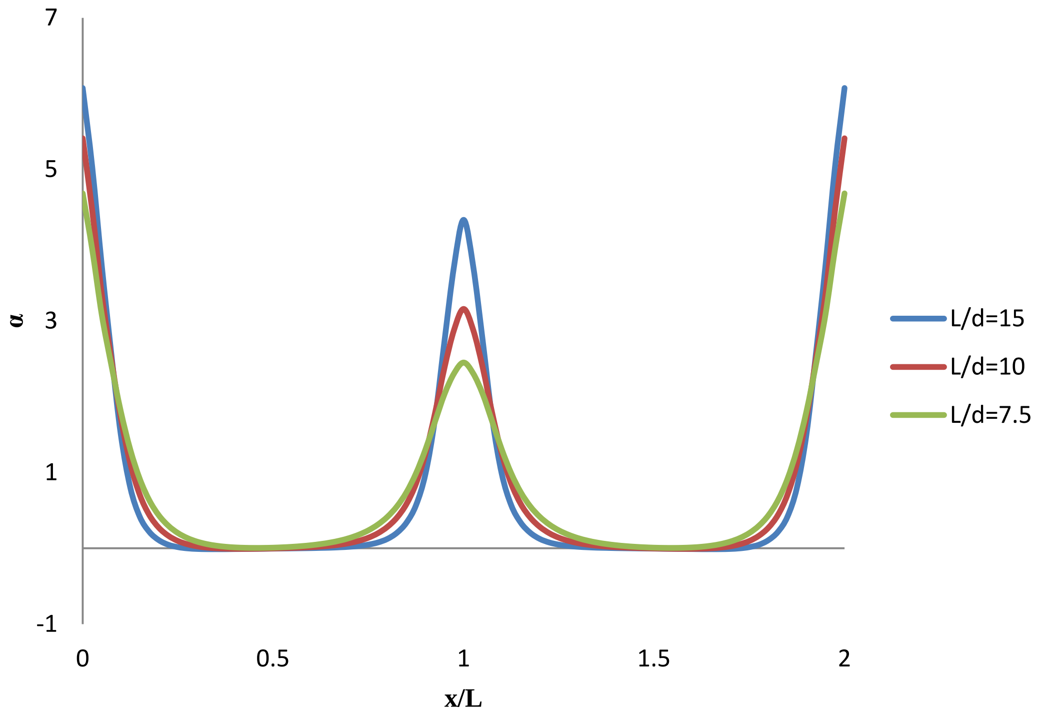
Fig. 4.6 shows the shear stress distribution for different models at level S1 and level S2 respectively. From Fig. 4.6(a), the shear stress increases quicker when the span/depth ratio becomes larger. However, after the peak of shear stress occurs, the shear stress drops also quicker if the span/depth ratio is larger. Besides, it is observed that when the span/depth ratio is larger, there are more portions near mid span that the shear stress closes to zero. For the shear stress shown in Fig. 4.6(b), it is observed that the shear stress is always larger if the span/depth ratio becomes larger.

4.3.2 Two span models

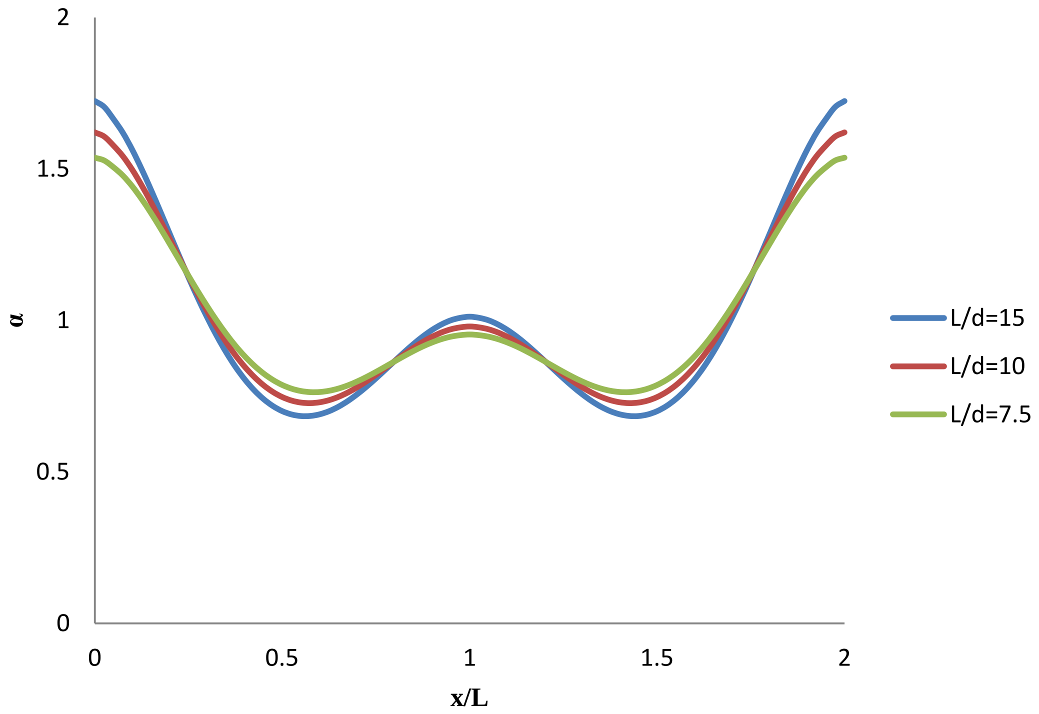
In this section, the three stresses obtained from three different models with different span/depth ratio will be compared with those one span models in Section 4.3.1.

1. Vertical stress

Below shows the vertical stress distribution for different models at level S1 and level S2.



(a) Variation of vertical stress at level S1



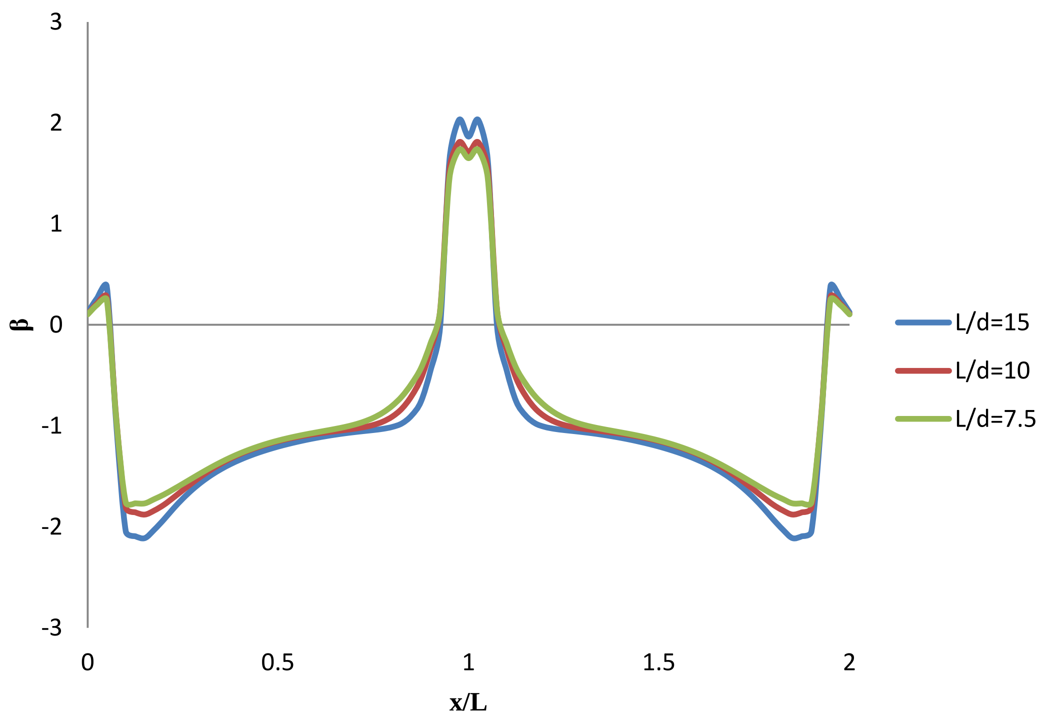
(b) Variation of vertical stress at level S2

Figure 4.6 Vertical stress for set E models

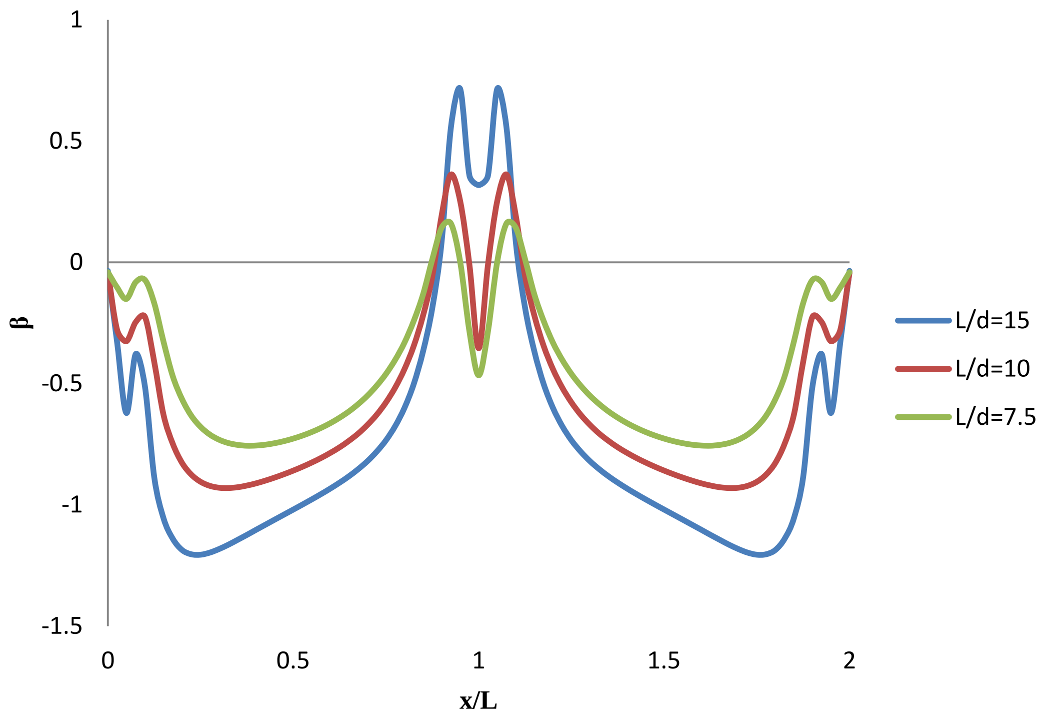
Fig. 4.7 shows the vertical stress distribution at different levels in the lower part of shear wall. The trends of vertical stress at each span are similar to one span case. However, the vertical stress increases quickly near the interior support and the vertical stress at interior support becomes larger when the span/depth ratio becomes larger.

2. Horizontal stress

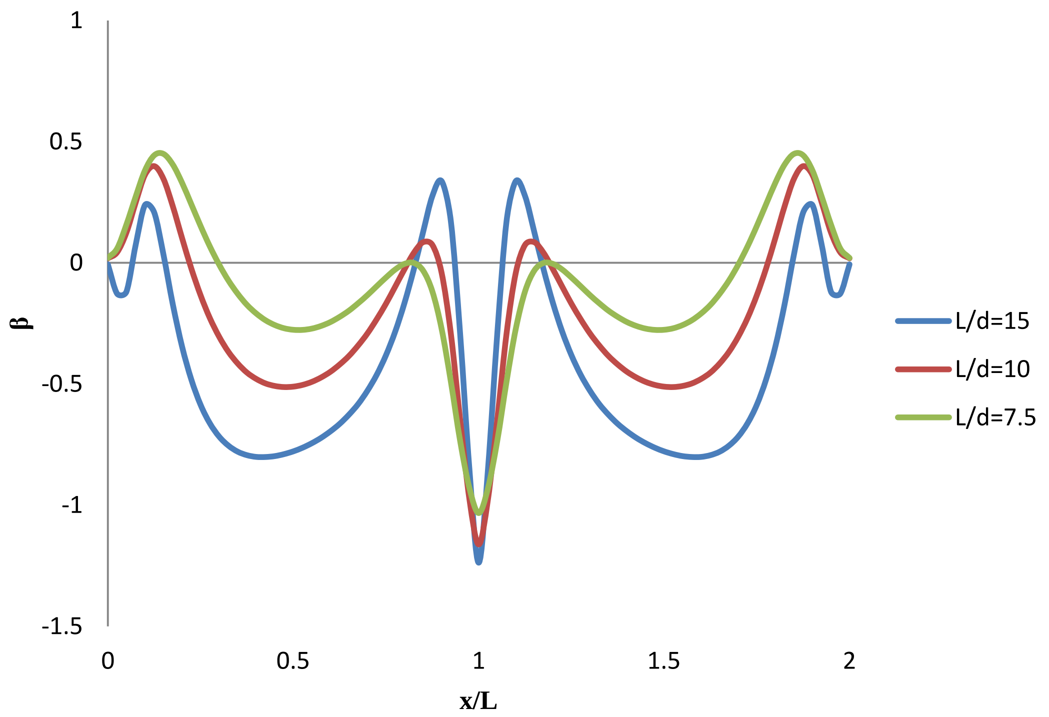
Below shows the horizontal stress distribution for different models at level T1, level T2 and level T3.



(a) Variation of horizontal stress at level T1



(b) Variation of horizontal stress at level T2



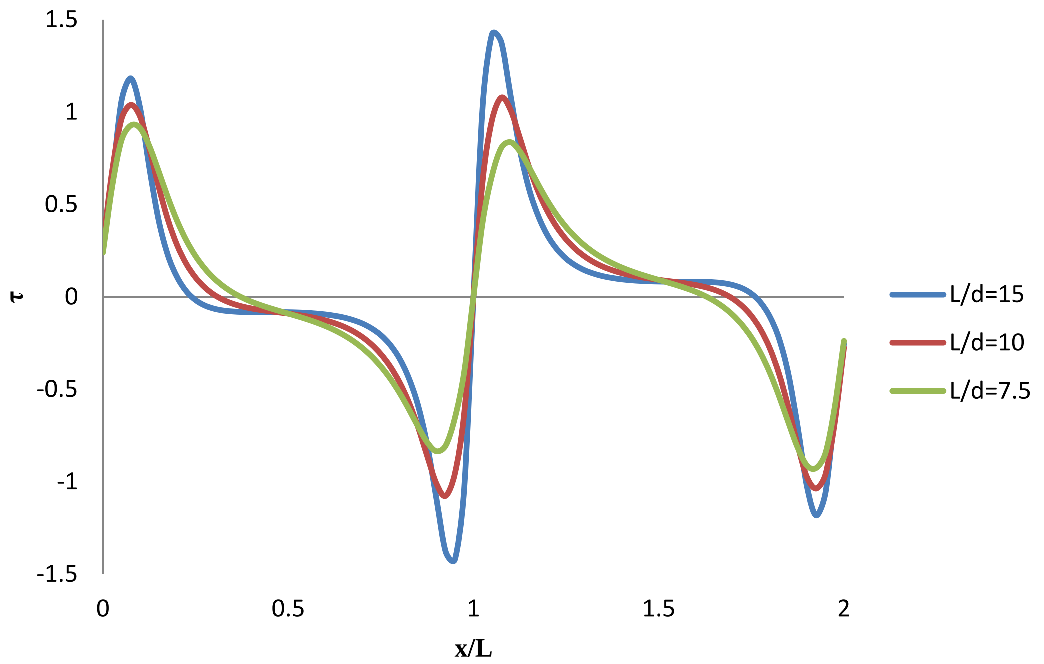
(c) Variation of horizontal stress at level T3

Figure 4.7 Horizontal stress for set E models

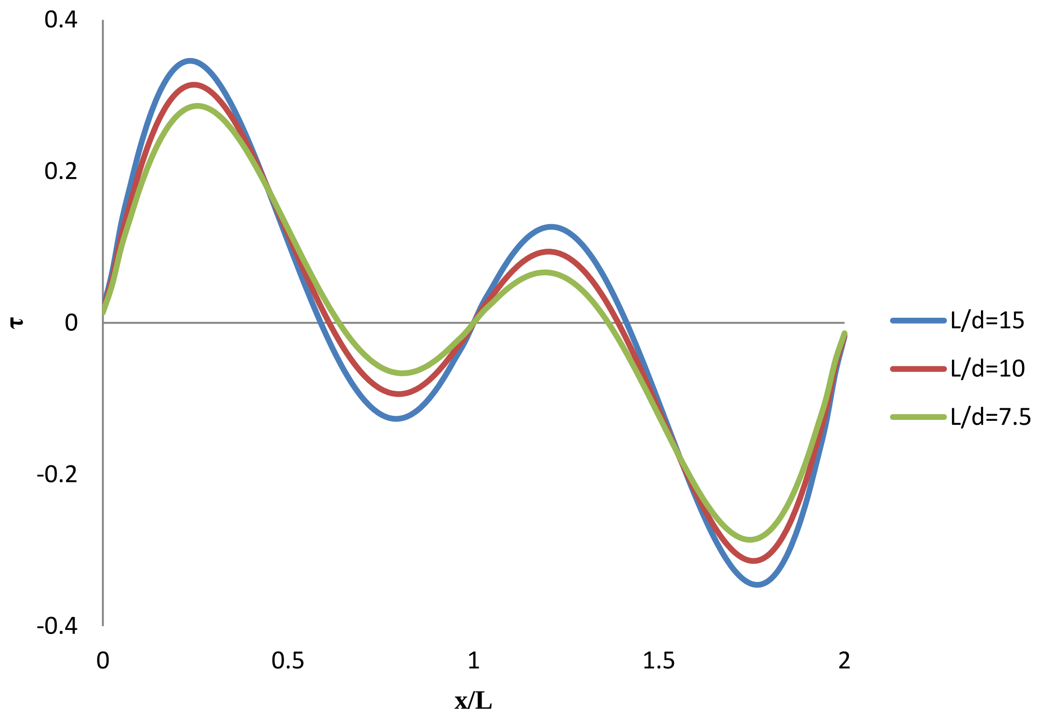
Fig. 4.8 shows the horizontal stress distribution for different models at different levels. Compare with Fig. 4.4 which is the horizontal stress distribution for one span model, the trends of distribution are also similar except near the interior column. At the level T1, the horizontal stress changes to compression quickly near the interior column. Besides, at the center line of interior column the horizontal stress drops down a little bit and this effect becomes more significant when the level of transfer beam becomes higher.

3. Shear stress

Below shows the shear stress distribution for different models at level S1 and level S2.



(a) Variation of shear stress at level S1



(b) Variation of shear stress at level S2

Figure 4.8 Shear stress for set E models

Fig. 4.9 shows the shear stress distribution at the lower part of shear wall for different models at different levels. It shows that the trend of shear stress for two span models and one span model is also similar. The different of shear stress distribution between two span is just midpoint symmetry.

4.3.3 Non-linear stress distribution effect in transfer beam

From Chapter 3, one of behavior of the transfer beam in shear wall-transfer beam system is that the distribution of horizontal stress along the depth of transfer beam becomes non-linear when the span of model becomes more, or says the span/depth ratio becomes lower. Fig. 3.4 shows the horizontal stress distribution along the depth of transfer beam is still linear for one span situation. However, the non-linear behavior of stress distribution occurs from the two span model and more significant in the three span model.

To investigate this kind of effect, a set of model have been generated to perform the finite element analysis. Consider five beams with different span/depth ratio but the depth of those beams is fixed as 2m. That means the span length various to control the span/depth ratio. The boundary condition for all of beams is simply supported and supporting the in-plane distribute load at the top face of the beam which magnitude is 100kN/m and the thickness of beam is 1m. The results show as below:

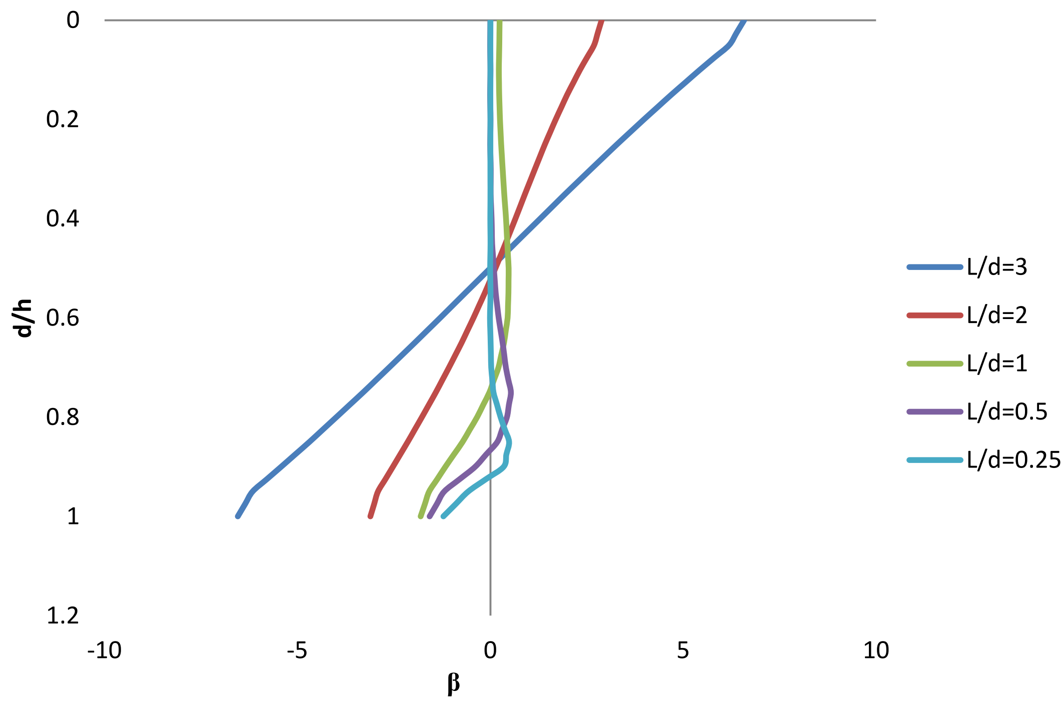


Figure 4.9 Horizontal stress for models

Fig. 4.10 shows the horizontal stress distribution for different models. From the L/d=0.5 model, the shape of horizontal stress distribution shows the linear distribution which is as like as a normal beam and the location of neutral axis is about the mid depth of the beam. However, when the span length/depth ratio becomes higher, the distribution becomes non-linear and the values of horizontal stress become lower for both compression region and tensile region. That means for a deep beam, the upper part of the beam will subject a smaller horizontal stress and tends to zero if the beam is deep enough. The stress will induce at the lower part of beam only therefore the location of neutral axis will become lower.

4.4 Summary

In this Chapter, the effect of stresses for one span and two span models due to span/depth ratio is investigated. Besides, the non-linear horizontal stress distribution effect in transfer beam due to span/depth ratio is also investigated.

1. Vertical stress

The results show that the vertical stress becomes larger when the span/depth ratio becomes larger at the column supports. However, the increase and decrease of vertical stress is also quicker when the span/depth ratio becomes larger. The different of trend for vertical stress between one span model and two span model is just there are sudden change at the interior column support for two span model.

2. Horizontal stress

The results show that the horizontal tensile stress becomes larger when the span/depth ratio becomes larger near the mid span. Compare to the one span and two span cases, the result shows that there is sudden change for horizontal stress near the interior support for two span models. Besides, the variation of horizontal stress due to span/depth ratio becomes smaller.

3. Shear stress

The results show that the shear stress becomes larger when the span/depth ratio becomes larger. However, the shear stress near mid span is close to zero at level S1.

Compare to the one span and two span models, the trend of shear stress distribution is also similar for different levels. Besides, the shear stress distribution is point symmetric at the midpoint of model for two span models.

4. Non-linear stress distribution effect in transfer beam

The horizontal stress distribution along the depth of transfer beam at mid span becomes non-linear when the span/depth ratio becomes smaller which means the beam becomes thicker. Besides, when the span/depth ratio becomes smaller, the upper part of beam is useless because the horizontal stress at the upper part of beam is zero. The compressive stress and tensile stress are presented at the lower part of the beam and those stresses are small.

CHAPTER 5 CONCLUSION

In this paper, three parameters, which are the number of span, the length of span and the span/depth ratio, would affect the structural behavior of a shear wall-transfer beam system are investigated.

5.1 Effects on structural behavior

The number of span decides the number of sudden change in stress. Usually the stress changes reversely because there is support which means the more boundary condition for the near elements. Besides, the length of span decides the shape of stresses. The longer length of span, the stresses would keep increasing or decreasing further until there is another column support. On the other hand, the span/depth ratio decides the also the trend of stresses and the magnitude of the stresses. Usually the stresses would be larger when the span/depth ratio becomes larger.

5.2 Recommendation for future study

After the investigation for the shear wall-transfer beam system based on the effect of span and the span/depth ratio, there are several directions for the future study about this topic:

1. Effect on loading

In this paper, the shear wall transfer beam system is subjected to an in-plane load at the top of shear wall. However, besides of in-plane load there is a lateral load like wind load which is also subjected by shear wall. The structural behavior of shear wall transfer beam system would be totally different if there is a lateral load adding on the shear wall.

2. Effect by other geometry parameter

The geometry of the shear wall-transfer beam system is one of the main factors that would affect the structural behavior. Besides of the number of span, length of span and the span/depth ratio, there are some of geometric parameters which can be investigated like the thickness ratio of shear wall and transfer beam, and the size of column.

3. Opening on shear wall

For a modern high-rise building, there are some opening on the shear wall to provide facade or ventilation area. However, the structural behavior of shear wall-transfer beam system would be affected much when there is any open area on the shear wall. Therefore, this is also one of direction for studying the effect of structural behavior due to open are on shear wall.

References

Jawaharlal, P. (1996), *Analysis and behavior of transfer girder system in tall buildings*, PhD Thesis, The Hong Kong University of Science and Technology, Hong Kong.

Kuang, J.S. and Jawaharlal, P. (1996), "Continuous transfer beams supporting in-plane loaded shear walls in tall buildings", *The Structural Design of Tall Buildings*, Vol.5, pp. 281-293.

Mir M. Ali and Kyoung, S. M. (2007), "Structural developments in tall buildings: current trends and future prospects", *Architectural Science Review*, Vol.50, No 3, pp. 205-223.

Yettram, A.L. and Hirst, M.S. (1971), "An elastic analysis for the composite action of walls supported on simple beams", *Buildings Sci.*, Vol.6, pp. 251-159.

Smith, B.S. and Riddington, J.R. (1977), "The composite behavior of elastic wall-beam systems", *Proc. Instn Civil Engrs*, Vol.63, No 2, pp. 377-391.